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Kenaf Research, Development and Commercialization

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Kenaf Research, Development, and Commercialization

Introduction

The mission of the Office of Agricultural Industrial Materials is to accelerate commercialization of non-food, non-feed industrial products from agricultural raw materials, both plant and animal. It is one of many programs which focus on providing U.S. farmers with alternative opportunities to traditional enterprises and practices in a changing domestic and global economy.

Commercialization efforts are generally beyond the research bench, i.e. post research activities. It is the process by which all functions within a system are raised above a threshold level required for a commercial firm to decide to undertake a business strategy to manufacture and market a product. The process may include targeted research and development to overcome specific technical and economic obstacles. This can be anywhere in the system of crop production, raw material processing, product development, product manufacturing including testing in prototype facilities, and product marketing. These post research activities also can include product and market testing, helping meet regulatory requirements, providing linkages and technical information to financial groups, identifying and working with entrepreneurs and champions, and working in private-public partnerships to move a product toward the marketplace. Once a firm decides to commercialize a product or technology, our role shifts to research, education, and extension in the agricultural sector to support emerging industries.

The Association for the Advancement of Industrial Corps (AAIC) held annual meetings in Peoria, Illinois on October 2-6, 1989. The October 5, 1989 agenda included an all-day session on kenaf with presentations on significant kenaf research/development efforts in the United States and Australia. The presentations were followed by an open, five-member panel discussion on needs for continued advancement toward commercialization of kenaf.

This publication reports all available presentations on kenaf from the AAIC conference. The analyses and opinions expressed or implied herein are solely those of the authors and do not necessarily represent the views of the U.S. Department of Agriculture or the Association for the Advancement of Industrial Crops.

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***DANIEL E. KUGLER**, Acting Director*
Agricultural Industrial Materials

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Kenaf: The Papermaking Fiber

By

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Kenaf (*Hibiscus cannabinus L.)* has long served diverse markets. For many decades perhaps centuries, certain varieties from the wild have been used as food, and the non-branching varieties have been bred, selected, and cultivated for textile fiber, i.e., rope, twine, burlap, and carpet felting. However, for the pulp and paper industry kenaf is a sleeping giant just waiting for the stimulating splash of a major pulp and paper conversion facility.

Kenaf consists of two major fiber types. The outer bark contains the bast fibers with an average length of 2.5 mm, while the woody core fibers average 0.6 mm. Pulps have been prepared by using several pulping techniques familiar to the industry. Those more prominent processes include kraft, soda, neutral sulfite, mechanical, chemimechanical, thermomechanical, and chemithermomechanical. We found that kenaf chemical pulps are superior to commercial hardwood pulps and, except for resistance to tear, are comparable to softwood pulps. Papermachine runs with various kenaf pulps provided from several pounds up to a ton of several grades of paper, including bond, surface sized, coating rawstock, and newsprint. The newsprint has been produced on a commercial scale. Experimental papers were printed with commercial presses by various techniques, e.g., letterpress, offset, rotogravure, flexograph, and intaglio.

Kenaf shows exceptional promise for newsprint; however, numerous exciting opportunities remain to be exploited. The giant is beginning to stir.

Preemergence Herbicides For Kenaf Production

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The commercial production of Kenaf in the Lower Rio Grande Valley of Texas will begin in the spring of 1990. At present, there are no pesticides labeled for use in kenaf production.

The objectives of this study are: 1) To test selected preemergence cotton herbicides for phytotoxicity and efficacy in kenaf; and 2) To obtain data on the performance of these herbicides to support expansion of registration on kenaf. Field experiments were established at Monte Alto, Texas in October of 1988 and at Weslaco, Texas in April 1989. Experiments were in randomized complete block designs with four replications. A single kenaf variety (Everglades 41) was used in both trials.

Treatments included trifluralin, pendimethalin (preplant incorporated, ppi) and ethalfluralin (preemergence, pre) at rates of 0.9 and 1.7 kg ai/ha; metolachlor (pre) at 1.7 and 3.4 kg ai/ha; alachlor (pre) at 2.3 and 4.5 kg ai/ha. PPI treatments were incorporated immediately after spraying by double discing to a depth of 3 inches. Trifluralin, pendimethalin, alachlor, at all application rates, and metolochlor at 3.4 kg/ha gave excellent (90%) control of weedy grasses. Acceptable (80%) control of all weeds (grasses and broadleaves) resulted from treatments of pendimethalin at 1.7 kg/ha, alachlor at 2.3 and 4.5 kg/ha, and metolachlor at 3.4 kg/ha. No visual injury symptoms were noted in kenaf from any treatment in either trial. Total plant dry weight was measured at 8 weeks after treatment at both locations and at 24 weeks at Weslaco. No differences were found in the dry weights at the 8 week measurements; however, significant dry weight differences were evident at 24 weeks post treatment. Yields from trifluralin and pendimethalin were not different from the untreated check but were less than from the other treatments.

These observed differences may be attributed to substantial competition from ragweed parthenium and other weed species not controlled by the herbicides. All five of these herbicides may eventually find a place in commercial kenaf production. The results from these trials suggest that alachlor or metolachlor may be the best choice for season long weed control in kenaf.

The Northern Territory Fibre Crops Program

By
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Abstract

Since 1987 the Department of Primary Industry & Fisheries has been investigating the feasibility of establishing a pulp and paper indusry based on kenaf and other non wood fibre crops. The direction of the program is to develop an indusry based on production from rain feed minimun-tillage farming systems in a tropical semi-arid (monsoonal) environment. The primary objective is to develop an attractive proposal for commerical investment.

The investigation has taken a innovative course (for a department of agriculture). All studies are aimed at establishing a suitable systems framework for further detailed investigation and to facilitate the early entry of private sector investment in continuing research and development and, ultimately, the industry. The investigation has included studies into crop agronomy, crop growth modelling, pulping tests and paper production technology, mill location analysis, marketing, and farm and mill economics.

A commercial investment proposal based on the results of the program so far has been prepared and presented to selected paper manufacturers in Europe and Asia. The continuing R&D program for 1989/90, designed to involve commercial participation, will include increased fibre production for laboratory and mill scale tests, further studies into pulping and bleaching technology, possible mill configuration and costs, harvesting-transport-storage, seed increase and cult ivation practices, and environmental studies.

Introduction

The Northern Territory (NT) fibre crops program originated during the significant devaluation of the Australian dollar in the mid 1980's. Some imported printing grade papers had become prohibitively expensive and publishers sought alternatives which could be locally produced. News Corporation, the publisher of the major newspaper in Darwin, (population 70,000), was one such company. In 1986 their local editor proposed a joint investigation with the NT Government into kenaf *(Hibiscus cannabinus)* which could be grown in the NT, and, as either a raw fibre or processed pulp, could be bulk transported for manufacture as magazine stock paper in the southern states of Australia.

The NT Government responded by requesting from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) the services of two scientists with extensive former experience in kenaf to assess the proposal. A report was hastily compiled agreeing that kenaf had considerable potential as a crop for the NT. The report recommended a series of investigations into agronomy, processing and marketing. Within this broad framework a Taskforce comprising representatives of a number of Government agencies with responsibilities in some aspect of the potential industry's development was formed in April 1987 to undertake the investigations. This was to prove too cumbersome and was later split into a smaller Taskforce of specialist workers dedicated to kenaf under the leadership of a Co-ordinator in the Department of Primary Industry and Fisheries (DPIF) and a larger, inter-agency, representative group for consultation and information.

Agronomic trials commenced in the 1986/87 growing season with seed increase plantings and a comparative study of growth at three habitats from the coast inland. This work quickly confirmed the crop's potential and although News Corporation subsequently lost interest, the NT Government approved, in March 1988, a major program of investigations costing $A760,000 for the 1988/89 financial year.

The Taskforce have since developed the fibre crops program in an innovative and unique way (for a department of agriculture). The kenaf produced in the program, however, is unremarkable in so far as it displays generally similar chemical and physical properties and pulp/paper making qualities to kenaf widely reported elsewhere and again by Dr. Marvin Bagby at this conference. Therefore, this paper will concentrate more on describing the process behind the NT program rather than the specific results so far derived from it.

Objectives And Planning

Nearly all previous work on kenaf in Australia had been under irrigated cultivation on the heavy clay soils of the Ord River Irrigation Area (OIA) in Western Australia as described by Ian Wood at this conference. This irrigated option was not readily available in the NT and agronomic investigations have been directed at the development of dry land (rain fed) systems. The potential area for kenaf in the NT is in the tropical monsoonal north of the Territory (known as the Top End) ranging from the generally accepted inland limit of rain-fed agriculture at about 800mm near Katherine to the coast where rainfall averages 1600mm annually. Nearly all rain falls in a hot wet season from November to April. Agricultural soils are mainly red clay loams or sandy loams, highly leached with low fertility and only moderate water holding capacities. They are susceptible to erosion and the use of minimum or zero tillage techniques will be essential to the development of sustainable farming systems.

Even greater challenges were presented in assessing the appropriate fibre processing technology with associated infrastructural and environmental requirements, available markets and economic parameters. While Government could determine the timing and scope of the investigations it was clear that the important decisions towards realizing the commercial potential of kenaf could only be made by private enterprise participants in the program. Consistent with these considerations the Taskforce gave early priority to setting an objective which would determine the priorities of the study. The result was: "To develop and refine continuously an attractive proposal for

commercial investment in a pulp/paper industry in the NT based on locally grown kenaf and perhaps other non-woody fibres".

To achieve that objective a wide ranging program of studies was developed as indicated on the flow chart at Figure 1 with a central focus directed to the preparation of a Commercial Investment Proposal (CIP).

Consultants were commissioned in various specialist fields to supplement the work of the in-house agronomists and economists of DPIF.

Systems Development

At an early stage it was evident that the large range of options to be evaluated called for the development of a matrix to provide a decision making framework and/or facilitate the entry of private sector investment into the program. This was to occur as the program progressed but certain basic studies required prompt attention.

Market Studies

Initially Jaakko-Poyry Pty Ltd provided a small first phase market overview of the non-wood sector of the world pulp/paper market. Their report indicated strong growth prospects in south east Asia but noted that active marketing programs of kenaf based pulps would be essential and this was confirmed by subsequent desk-top studies by economists of DPIF reviewing published sources.

Later in the program these studies were to be substantially advanced in connection with the preparation of the CIP.

Pulping Technology

The 1987/88 test crops were sufficient to produce samples for extensive testing and two major studies were commissioned to assess the characteristics of NT kenaf under several pulping processes.

Voest-Alpine Industrieanlagenbau Gmbh, Linz, Austria carried out a comprehensive range of tests on 400 kg of whole stem kenaf grown on two of the major soils to:

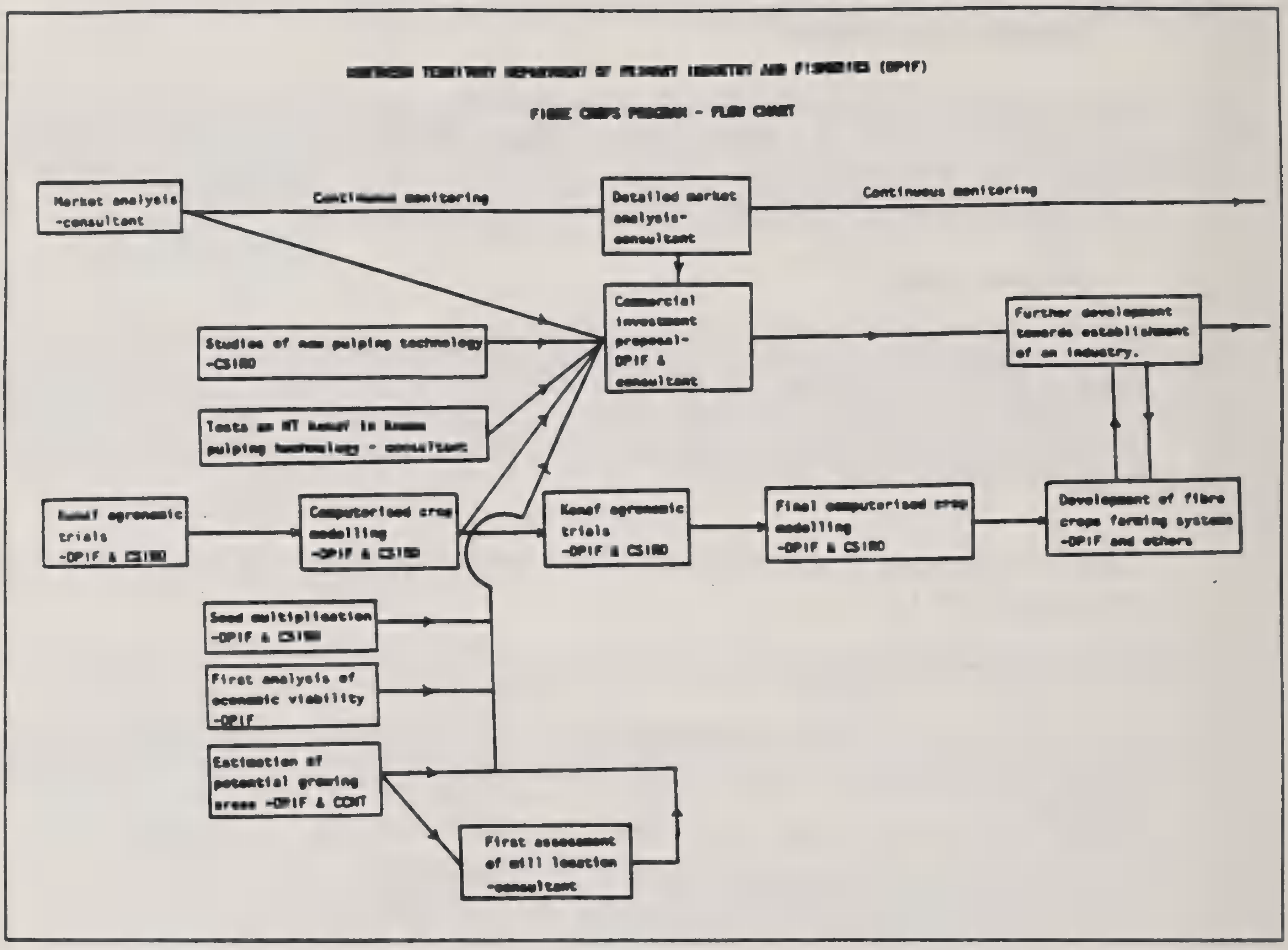
- assess pulping quality using the soda anthraquinone (Soda-AQ) process.
- manufacture machine and hand made paper for quality assessment and presentation purposes.

AMCOR Research and Technology Centre, Alphington, Victoria, also carried out extensive laboratory scale tests on NT kenaf using whole stem, bark and core and three processes - Kraft, Soda and Soda-AQ and tests were conducted to establish the suitability of DARS (Direct Alkali Recovery System) technology for treatment of the residual black cooking liquor.

A Canadian consultant, Arbokem Inc. assisted in the interpretation of the results and provided a spread sheet configuration for comparative costing of chemical processes. New pulping technology tests which were to have been done in 1988/89 (Fig. 1) were not carried out and have been deferred for completion in the 1989/90 financial year program.

Figure 1. Northern Territory Department of Primary Industry and Fisheries (DPIF) .

Fibre Crops Program - Flow Chart



Agronomy

The traditional agronomic approach involves the slow accretion of data and experience of a crop under local conditions by empirical trial methods. The transfer of technology from other farming systems or localities is of limited usefulness as there is often no basic index of growth parameters for comparison and each site tends to be unique in climatic, edaphic and biological terms. Trials are invariably expensive in money, manpower and time. While no firm time-frame was dictated by Government there was an expectation of significant results from the program in less than five

years. There was insufficient time for the traditional agronomic approach and new methods were required.

Scientists from CSIRO were contracted to work in collaboration with DPIF staff to develop and validate a crop growth simulation model to rapidly test the influence of crop phenology, local climatic factors and nutrition on the probability of obtaining different yields at different locations in the NT. A feature of the NT wet season is high variability in amount and duration of rainfall which can have severe consequences on crops where reproductive parts comprise the economic yield. In contrast the economic yield of kenaf is vegetative material and productivity may be more stable. The use of long term weather data in conjunction with the model will allow a full analysis of climatic risks critical to economic success.

When validated the model could also provide an objective guide for selection, breeding and genetics in the continuing development of varieties with more desirable characteristics or more suitable for each regional climate.

Experimental work conducted by CSIRO and DPIF in 1988/89 season was principally in connection with the development and validation of the model. Further empirical work is now continuing to evaluate other growth characteristics, crop establishment and fertilizer use.

The need to provide potential farmers (and DPIF) with experience in larger scale production at an early stage has required the introduction of a farm development project to run concurrently with experimental work. Separate areas totalling 4 ha were grown on private properties during the 1988/89 season and this area will be increased progressively during the course of the program.

Results so far indicate that under favorable conditions kenaf can yield up to 13 tonnes/ha and that kenaf may have a lower than anticipated demand for nitrogenous fertilizer. There are indications that the plant can effectively utilize N accumulated in the soil profile and if this is validated by further research it could have significant implications for crop rotation systems and the economics of production.

Seed Multiplication

The variety of *H. cannabinus* most used for research in Australia has been Guatemala-4, obtained originally by CSIRO along with an extensive germplasm collection from the USDA. A project has been instituted to build up stocks of clean seed lines of G4 for future farm development and CSIRO is co-operating by regenerating all lines of the germplasm collection and selecting lines for further testing in the NT. These include lines with relative resistance to nematodes, lines of roselle *(H. sabdariffa)*, and lines of other potential fibre crops, Sunn hemp (*Crotalaria juncea)*, Sesbania (*Sesbania cannabina)* and Congo jute (*Urena lobata)*.

The introduction of other non-wood fibre sources to complement kenaf gives a potential for future advantages in allowing for pulp blends, in a reduction of dependence on a single crop source and the development of crop rotational systems especially if one crop is a legume.

Hence, of course, the derivation of the title of the NT program.

Mill Location Analysis

The location of a pulp mill raises complex questions many of which can only be answered in a fully commercial environment. Factors such as: location in respect of growing area and port of export; road or other transport modes; security of raw material supply; availability of chemicals, power and water; workforce and accommodation, and environmental considerations must be precisely evaluated. Clearly a method or system of analysis is the essential first step and Taskforce commissioned BHP Engineering of Perth, Western Australia, specifically to develop a computer model spreadsheet to accommodate the broad matrix of factors to be considered in deciding the most cost-effective location of a pulp/paper mill. Included on the matrix are five pulping processes (Kraft, Soda-AQ, NACO, CTMP and NSSC) at four annual output capacities - 10,000 20,000 50,000 and 100,000 tonnes. The model consists of four basic sections: process capacity analysis, capital- and operating expenditure and financial analysis. Mill sites were selected in the analysis but only to validate the operation of the model.

The estimation of growing areas also provided an opportunity to integrate the mill location analysis with a program being independently developed by the Conservation Commission of the NT (CCNT) where extensive soil and vegetation data were being logged into an ARC-INFO geographic information system. A joint project allowed extensive detailed soils data in one major area to be entered into the system and products to be tested which would later be used in the CIP and further mill location analyses. The area selected was one of several with significant potential in the Daly River Basin and is centred on the DPIF Douglas Daly Research Farm as shown in Fig. 2.

Based on a very conservative production estimate of 5 tonnes of fibre each year the areas required to service a Soda-AQ mill at the four capacities used in the analysis are shown in Fig. 3.

The mill location analysis also identified a range of environmental factors which will be highly influential in any ultimate decision on location. These are: the nature of the existing environment, mill wastes (gaseous liquid and solids), reagent handling, occupational health and safety, noise, transport of toxic materials, local and regional traffic impact, construction phase and other local impacts. Projects will be developed starting in 1989/90 to give each of these factors detailed study.

The Wesley-Vale (Tasmania) case where a proposal for a major 400,000 tonne/year bleached kraft eucalypt mill was defeated on environmental grounds is a manifestation of a significant shift in the climate of opinion on pollution producing mills. The Federal Government of Australia is preparing guidelines for bleached kraft mills but it can be reasonably presumed in future that no proposal, irrespective of scale or process, will be approved without thorough environmental analysis.

Figure 2. Map of the Top End (lower latitudes) ofthe Northern Territory with sechematic representations of potential growing areas for kenaf.

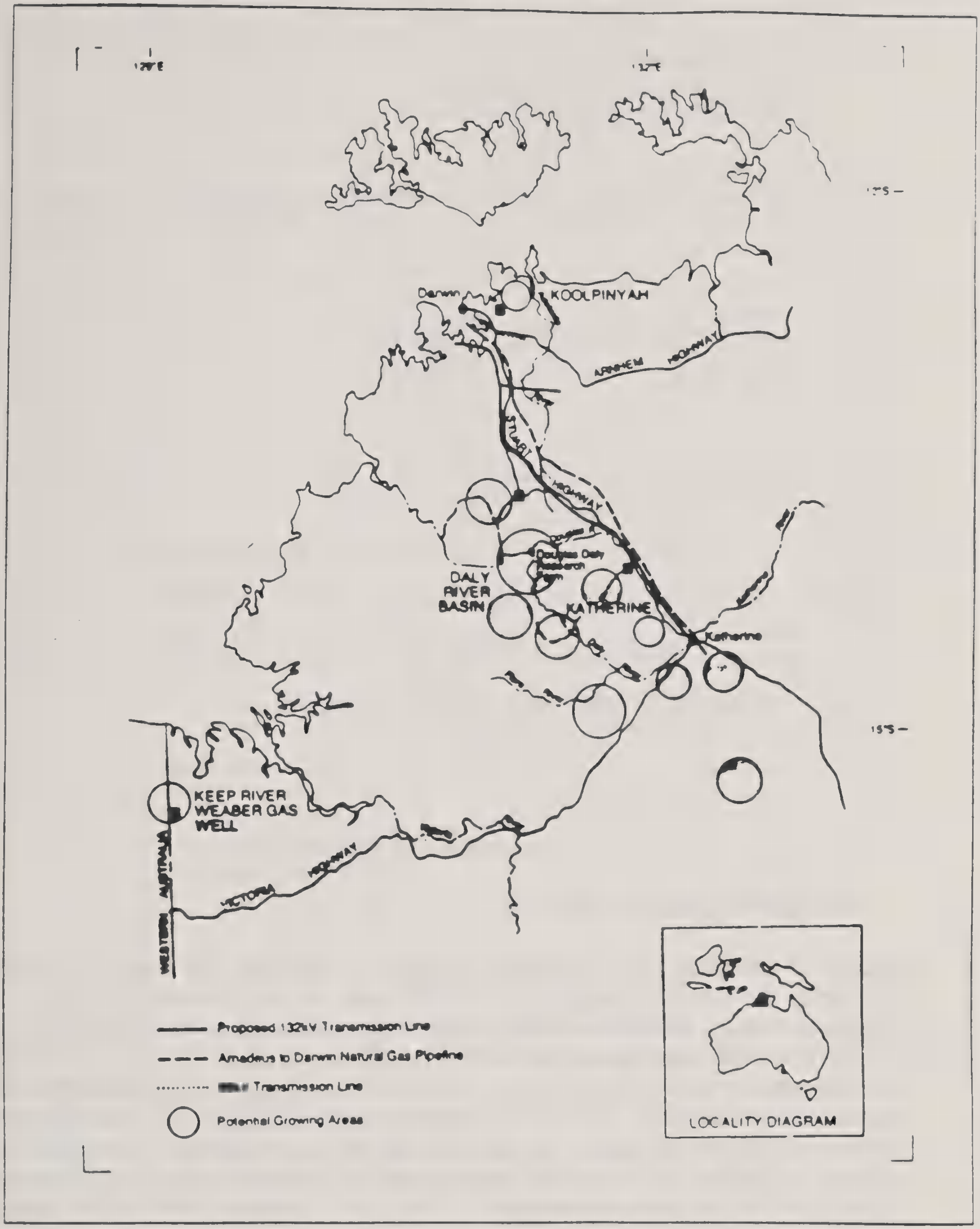


Figure 3. Northern Territory Department of Primary Industry and Fisheries

FIBRE CROPS PROGRAM

GROWING AREAS

Estimated arable areas in four growing regions of the Northern Territory.

	ha
Koolpinyah	11,000
Daly River Basin	120,000
Katherine	200,000
Keep River	14,440

Estimated annual kenaf and growing area requirements for a Soda AQ pulp mill.

	Total Pulp Production (t/yr)			
	10,000	20,000	50,000	100,000
Kenaf (t)	23,004	46,007	115,018	230,037
Growing Area (ha)	4,600	9,200	23,000	46,000

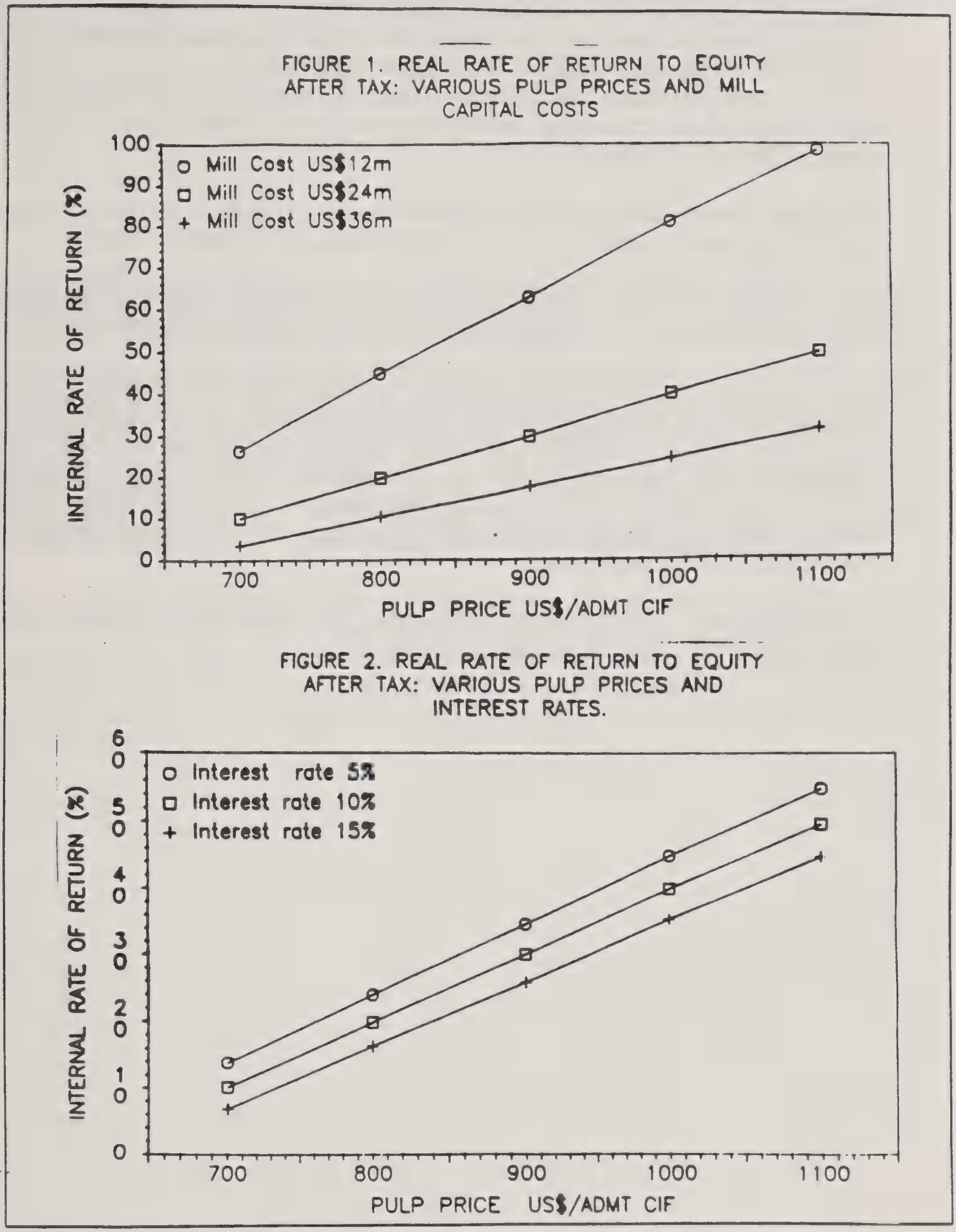
Source: BHP Engineering (unpublished)

Synthesis And Progress

First Stage Economic Analysis

Analysis of economic viability of kenaf production at farm and mill levels has been studied in-house by the agricultural economists of DPIF using data accumulated from the projects on process technology, marketing, agronomy and mill location. In many respects the economic analyses represents major synthesis of these component studies in the NT program. Assumptions are confounded by the number of process, scale, equipment, location and capital cost options still under active consideration. The contrast in quality between bark, core and whole stem pulps and the range of markets (and prices) for each also tends to further confound. Once again these are issues to be resolved by commercial interests and the economic synthesis has concentrated on producing a framework on which viability is tested in a variety of conditions as shown in the example at Fig. 4.

Figure 4. (Figure 1. Real Rate of Return to Equity After Tax: Various Pulp Prices and Mill Capital Costs). (Figure 2. Real Rate of Return to Equity After Tax: Various Pulp Prices and Interest Rates).



Commercial Investment Proposal

The results of the full range of projects have been integrated into a comprehensive package of information for presentation to prospective buyers of pulp who may be prepared to invest, or to participate, in the continuing assessment of the potential for a pulp/paper industry in the NT and, ultimately, in the industry itself. Further detailed market analysis and market intelligence by consultants in England and Canada identified first round target companies from among mostly higher quality specialty grade paper manufacturers in Asia and Europe and the CIP was presented to them in August and September 1989.

To facilitate planning and in anticipation of the entry of an investor or investors to the program a revised objective for the program beyond 1989/90 has been developed to read:

"To continue the program of investigations to allow a full feasibility study into the potential for a paper pulp industry in the Northern Territory based on kenaf and other non-woody fibres".

Studies are in place for 1989/90 which are designed so that a commercial investor can join at any stage and the NT Government has recently approved a budget of a further $A700,000 for these studies. Priorities in the program will include increased fibre production from larger farm demonstration areas for both laboratory and mill scale tests; further studies into pulping and bleaching technologies; possible mill configuration and costs; studies into the most appropriate harvest, transport and storage system for the NT environment; cultivation practices and seed increase; and environmental studies.

Acknowledgement. I would like to acknowledge the assistance of Dr Wayne Mollah, the Taskforce Co-ordinator, in the preparation of this paper.

Kenaf Grown As A Forage Crop In Northeast Texas

By
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In order to develop an immediate use for the kenaf as a marketable crop, Ladonia Market Center, Inc. planted G-4 variety 4 miles East of Ladonia, Texas, April 26, 1989. The ground was broken 18" deep and planted partially on centers of 10", 20" and 30", No irrigation was used. Rainfall averaged about .27" per day or about 8" per month. The land was sandy loam. A week before planting 150 Pounds of urea, 25 pounds phosphorus, 25 pounds of potash, / acre was applied. No herbicides were used on the area set aside to be used for forage, but fusilade was sprayed on the portion set aside to be harvested for fiber June 1, 1989. 24 oz./ acre was applied to kill Johnson grass. Forage was harvested at 97 days. Dry weight of harvest averaged 4.6 tons/acre on 10" centers and 6.24 tons/acre on 30" centers. None of the 20" center planting was harvested. Within 24 hours the stalks that were cut were putting on new leaves and beginning to regrow.

It is our conclusion that the abundance of rainfall this year retarded the potential growth of the plants. This is evident from the photography we have that shows smaller, less healthy plants in the water retaining areas. Kenaf is a simple crop to grow and is definitely a good alternate crop for cotton in the area where we are farming. We are in the process at this time of developing small rural community uses such as forage cubes for farm animals to provide an immediate market for produce derived.

Kenaf Development In The United States: Now And The Nineties

By
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In 1986, the Kenaf Demonstration Project was organized, designed and implemented through a partnership, team effort between Kenaf International and USDA's Cooperative State Research Service. Major barriers to commercialization of kenaf for use in newsprint manufacture were identified and steps outlined to progressively remove those barriers. The Project team quickly grew to include Combustion Engineering's Sprout-Bauer division for fiber handling and pulping technology, Canadian Pacific Forest Products for newsprint manufacturing and mill operations, and the Beloit Corporation for papermaking technology and research. The full scale pressroom run of The Bakersfield Californian using kenaf newsprint on July 13, 1987 was an event of international importance. It spawned the first business plans to build and operate a kenaf newsprint mill in South Texas, plans which are likely to become actionable in 1989. Even as the Californian came off the press, the team was joined by H. Willett and Associates and Rio Farms Inc. to design a kenaf harvest system suitable for Lower Rio Grande Valley, Texas, conditions. Successful field testing near a proposed newsprint mill site in October 1988 was another event of international importance.

During 1988, Department of Agriculture research programs were started by the Agricultural Research Service at field stations in Weslaco, Texas, and Lane, Oklahoma. These programs marked the restart of agricultural research by USDA after a 10 year interruption. A third agricultural research was initiated in 1989 through the Agricultural Research Service by Mississippi State University.

Two current projects of future importance to kenaf becoming a major crop are fiber separation and wet paper product research. Other ongoing work with kenaf includes blending with deink (recycled) newsprint, blending with southern pine, municipal sludge composting with core fiber, fruit boxes from dry-forming, poultry litter with core fiber, and polymer analyses.

In the 1990s, kenaf will come of age with many uses for wholestalk and for separated fibers. Use as a supplemental fiber for existing pulp and paper operations is most likely to become the largest application. Multiple product operations at single locations are the most likely organization.

Effect Of Herbicides On Kenaf

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Preemergence and postemergence Herbicide trials were conducted in 1989 near Charleston, MS on a silt loam soil and a postemergence trial was conducted at Metcalf, MS on a silty clay loam soil, to evaluate kenaf Hibiscus cannabinus) tolerance. Herbicides (kg ai/ha) applied preemergence were fluometuron (2.0), norflurazon (2.0), cyanazine (2.0), ethalfluralin (1.0), pendimethalin (1.3), metolachlor (3.0), metribuzin (.5), diuron (1.3), clomazone (1.7), imazaquin (.17), chlorimuron/metribuzin (Canopy) (.5), alachlor (3.4), atrazine (2.7), and imazethapyr (.08). MSMA (2.2), acifluorfen (.42), bentazon (.8), imazaquin (.07), imazethapyr (.04), lactofen (.17), chlorimuron (.009), fomesafen (.28), and AC263-222 Cadre (.03), were evaluated as postemergence treatments at Charleston and acifluorfen, bentazon, imazaquin, imazethapyr, chlorimuron, lactofen, fomesafen, AC263-222, (same rates as at Charleston), fluazifop-P (.22), sethoxydim (.21), quizalofop (.07), clethodim (.11), sulfometuron (.02), metsulfuron (.009), and MSMA (2.2), were evaluated as postemergence treatments at Metcalf. Kenaf was planted at Charleston and the preemergence study was treated on June 12, 1989, and replanted on June 21 because of excessive rainfall. The postemergence study was not replanted and 35 cm kenaf was treated on July 17, 1989. The study at Metcalf was planted on July 10, 1989 and cotyledonary-to 1-leaf kenaf was treated on July 21, 1989. Herbicides were applied with a CO2 backpack sprayer delivering 225 L/ha in the preemergence study , and 187 L/ha in the postemergence studies. Plots were arranged in a randomized complete block design with four replications. All data were subjected to analysis of variance and treatment means were compared using Least Significant Difference (LSD) at the P=0.05 level of significance.

Visual injury ratings were recorded one week after emergence in the preemergence study. Norflurazon, diuron, clomazone, Canopy, atrazine and imazethapyr significantly injured kenaf. Four weeks after emergence, kenaf treated with norflurazon or clomazone had recovered from injury symptoms while the other treatments were still showing signs of significant injury. At this rating however, metribuzin and imazaquin were displaying significant injury symptoms. All treatments resulting in significant visual injury symptoms at the 4 week rating significantly stunted the plants.

Visual injury ratings were recorded 1 week following the postemergence treatments at Charleston and all herbicides significantly injured Kenaf when compared to the untreated control. Sixteen days following treatment, only the MSMA and bentazon treatments were free of visual injury. However, all treatments with the exception of MSMA reduced kenaf height significantly.

All herbicides applied at Metcalf with the exception of fluazifop-p, sethoxydim, quizalofop, clethodim, and MSMA resulted in significant visual injury to kenaf at 5 and 10 days following treatment. Plots were rated 25 days following herbicide application and treatments that caused initial injury to kenaf were still exhibiting significant injury symptoms expressed in height reduction.

Nutritive Value of Immature Whole Plant Kenaf and Mature Kenaf Tops For Growing Ruminants

By

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El Reno, Oklahoma

Introduction

A major component of the agricultural industry in the Southern Great Plains is the production and growth of ruminant livestock, such as sheep and cattle. Ruminants are particularly efficient in converting fibrous plant resources into marketable products that have a greater value than the raw materials, by taking the protein and fiber synthesized by the plant and converting it into high quality meat protein or fiber. Non-traditional plants, such as kenaf have gained a lot of interest recently as a source of pulp and other industrial fibers, but would be more quickly accepted in the Southern Plains Area if there were more diverse uses for the plant, especially an animal component. Utilizing the by-products from the harvesting and processing of the raw material or the whole plant as an ingredient in the diet of ruminants would add stability and diversity to kenaf production. The objective of the following research was to determine the nutritive value of kenaf as an ingredient in the diets of growing ruminants.

Materials and Methods

Two experiments were conducted at the USDA-ARS Forage and Livestock Research Laboratory at El Reno, Oklahoma, located 45 km west of Oklahoma City in an 85 cm rainfall area. In the first experiment (1988) fresh immature whole plant kenaf was used as the single ingredient in the diet of growing lambs. In the second experiment (1989) mature kenaf tops from three different varieties of kenaf were used as 10% of the diet.

In Experiment 1, kenaf (variety Everglade 41) was planted in May 1988 in 81 cm rows, fertilized with 100 kg of N per ha and irrigated only to insure survival of the plants. The whole plant was harvested in August after 90 days of growth at a stubble height of 10 cm, chopped into 25 cm sections and fed fresh once daily to 6 lambs. The lambs were cross-bred wether lambs weighing an average of 34 kg. Whole plant kenaf was the only ingredient of the diet. The lambs were allowed 10 days to adapt to the individual digestion stalls and to the kenaf diet. Following the adaptation period total collection of feces and urine was conducted for five days to determine the digestibility of the immature kenaf plant.

Mature kenaf tops used in Experiment 2 were harvested from mature plants representing three different varieties of kenaf, Everglade 41, Everglade 71 and C2032. Tops were collected following

desiccation of the standing plant after exposure to freezing temperatures. All varieties had been planted in May and managed in a similar manner. A split plot design was imposed across all varieties to study the affects of different levels of moisture and N fertilization on fiber production. Tops used in Experiment 2 were harvested across all water and fertility treatments. The whole plant was cut by hand and the top 100 cm removed, ground to a particle size of 1.2 cm by a commercial hammer mill and stored for 90 days before feeding.

A diet of 40% alfalfa pellets and 60% ground corn was used as the basal diet and kenaf tops were added to the basal diet as 10% of the dry matter. Twenty-eight cross-bred wether lambs (average weight 36.8 kg) were randomly assigned to either the basal diet or the basal diet plus tops from one of the three different varieties. The diets were fed for 10 days followed by a 4-day collection period to determine digestibility.

Samples of all diets as they were fed, the portion of the diet not consumed by the lamb and the feces collected were analyzed for dry matter, neutral detergent fiber (NDF), acid detergent fiber (ADF) and nitrogen (N). Nitrogen concentration was converted to crude protein concentration by multiplying the N % by 6.25. Digestibility of the different nutrients were calculated as (amount consumed - amount in feces)/amount consumed.

Data were analyzed by analysis of variance procedure using a completely randomized design. The individual animal was the experimental unit and differences among means were determined using the honest significant difference procedure as described by Steel and Torrie (1960).

Results and Discussion

Lambs readily consumed the leaf and stem portion of the plant, but refused to consume the woody stalk portion. The lambs were fed 3,221 (Standard Deviation; SD 37.4) g of fresh material once daily, which contained 887 (SD 10.5) g of dry matter. Because the lambs only consumed 51% of the material offered, daily dry matter intake dropped to 455 g which was about half of the amount needed to meet the daily dry matter requirement for maintenance of body weight (NRC, 1985). As a result all lambs lost weight during the 15-day experimental period.

Samples of whole plants collected during the feeding period were hand separated into stalk and leaf-stem portions, weighed, dried at 65 C for 72 h and weighed again. The stalk portion made up 60% of the total plant dry matter and the leaf-stem portion made up 40% of the total plant dry matter. Both portions had similar dry matter content of 23% and 21% respectively. From these data we concluded that the lambs were consuming all of the leaf-stem, plus the top portion of the stalk, since the lambs consumed 51% of the dry matter fed and the leaf-stem comprises only 40% of the plant dry matter.

The nutrient composition of the whole plant, stalk and leaf-stem portions are shown in Table 1. To determine the chemical composition of feed ingredients and to estimate the potential for the utilization of those plant nutrients for use by the animal, a sample of the plant is exposed to a neutral detergent solution which removes the cell contents. The remaining fraction is the neutral detergent fiber (NDF). Then an acid detergent solutions is applied to the NDF residue to remove the hemicellulose (HEMI). The resulting residue is the acid detergent fiber (ADF). The cell

contents are very digestible, so as NDF increases the amount of cell contents decreases and digestibility will decline also. The NDF fraction is partially digestible, but the extent and speed of that digestion is dependent upon how much ADF is found in the NDF. The ADF fraction contains the less digestible portions of the plant fiber.

The data in Table 1 shows that the majority of digestible plant fiber, soluble nutrients and protein are located in the leaf-stem portion, which was readily consumed by the lambs. The stalk portion contains over 90% of the NDF and the ADF, 80% of the HEMI and only 20% of the N found in the whole plant. The leaf stem portion contains less than 10% of the fiber, over 90% of the cell contents and 80% of the nitrogen. Therefore, the leaf-stem portion has the majority of the nutrients that would be available for digestion by the animal.

Table 1. Chemical composition of whole plant, stalk and leaf-stem portions ofthe fresh kenaf

		Plant part	
Item[a]	Total plant	Stalk	Leaf - stem
NDF	42.9	65.7	8.7
ADF	32.6	52.1	3.5
HEMI	10.3	13.6	5.2
N	2.74	.94	5.4
Crude Protein	17.1	5.9	34.0

[a]Expressed as a percentage of the dry matter

The data from Experiment 1 are similar to those reported by Swingle et al. (1978). They reported proportions of stalk and leaf-stem as a percentage of the dry matter to be 57% and 43%, respectively. The NDF, ADF and N content of the various portions of the immature kenaf plant were similar to those in our study. Data from Experiment 1 was also similar to that reported by Cahilly (1967). He determined that kenaf leaves contained 27% crude protein and less than 9% fiber.

The nutritive value of ingredients typically used in ruminant diets are listed in Table 2. The fresh leaf-stem portion of kenaf has a low fiber content, which is common for a dense energy source such as corn, oat, or wheat grain. The leaf-stem portion also has less fiber and more N than the commonly used high protein forages such as alfalfa hay and wheat forage. Soybean meal (SBOM) and cottonseed meal (CSM) are used as protein supplements to ruminant diets. Kenaf leaf-stem has a similar fiber content, but a lower nitrogen content than these sources of protein.

Table 2. Chemical composition of cereal grains, forages and protein supplements used in ruminant diets.

Feedstuff	Dry Matter	NDF	ADF	N
Corn	90	14	5	1.8
Oat	90	32	16	3.4
Wheat	90	14	8	2.8
Wheat Forage	22	52	30	2.7
Alfalfa hay	90	46	35	2.7
CSM	93	28	20	7.1
SBOM	89	8	6	8.0
Kenaf leaf - stem	25	9	3	5.4

[a] Composition values are from Nutrient Requirements for Beef Cattle, National Research Council, 1984, except for kenaf, which were de termined. All values are expressed as a % of dry matter.

The digestibility of the leaf-stem portion as determined in our experiment was excellent. Digestibility of dry matter (DM), NDF and ADF were 82.4 (SD 0.70) %, 69.9 (SD 2.65) % and 66.7 (SD 3.9) %, respectively. These values reflect the low indigestible fiber content of the leaf-stem portion and the high cell content concentration, such as is found in cereal grains. Powell and Wing (1967) harvested kenaf as silage after 90 days of growth and reported DM digestibility of 58 and 64%, which is lower than the values reported in this paper. During the ensiling process soluble carbohydrates are fermented by bacteria to acids which preserve the material during storage. However, this fermentation procedure can utilize energy that would have been available to the animal if it was fed fresh. Digestibility of fresh forage should be higher than the ensiled forage.

Table 3. Dry matter intake, fiber digestion, N intake, N digestion and N retention of the basal diet and the basal diet with 10% kenaf tops.

	Diet				
Item	Basal	Everglade 41	Everglade 71	C2032	SEM
DM intake, g/d	1094	1093	1188	1106	47.9
DM digestibility, %	74.01^{d}	73.23^{d}	72.10^{de}	68.44^{e}	1.63
Digestibility as percent of dry matter;					
NDF	54.98^{a}	56.08^{a}	30.34^{b}	39.80^{b}	3.29
ADF	44.25^{a}	48.95^{a}	8.55^{b}	15.02b	4.70
N	71.08	69.67	67.65	65.03	2.15
N intake g/d	24.3^{de}	25.8^{d}	236^{de}	21.9^{e}	1.02
N retention;					
Grams/d	7.98^{ab}	9.55^{a}	7.66^{ab}	5.18^{b}	0.88
Retained as a % of N intake	33.1^{de}	36.7^{d}	32.4^{de}	23.6^{e}	3.50

abcp <.01. defp <.05. SEM = Standard Error of the Mean

Kenaf leaf dried and ground into a meal was compared to alfalfa meal as a feed additive (Suryajantratong et al., 1973). Kenaf meal had a crude protein content ranging from 21 to 30% and a fiber content of 11-12%. The DM and crude protein digestibility of the kenaf supplemented diets were greater ($P<.01$) than the digestibility of the alfalfa meal suPPlemented diets- Protein from kenaf leaves should be equal to alfalfa protein since the amino acid composition of kenaf leaves was similar to alfalfa (Cahilly, 1967).

The nitrogen fraction of the leaf-stem portion in Experiment 1was 91.9 (SD 1.17) % digestible, which is characteristic of a N source found in plant material with a low fiber concentration. However, availability of the N is only one factor in determining the utilization of that N by the animal. Ruminants have a symbiotic relationship with a bacterial and protozoal population that inhabit the digestive tract. The microbial population utilizes the energy and N found in the plant to synthesis microbial protein to increase the microbial population. The ruminant utilizes the by-products of the microbial fermentation as an energy source and the microbial protein as a source of amino acids. Plant protein and simple carbohydrates that escape microbial fermentation are digested by enzymatic hydrolysis along with the microbial products in the lower tract of the animal. If plant N is released to quickly or without adequate available energy to incorporate it into microbial protein, then the N is released as free ammonia, absorbed by the animal and excreted in the urine. Thus, a highly digestible N component must be coupled with a readily available energy source if it is to be of value to the animal. Fresh kenaf leaf-stem has both readily available N and energy. When kenaf was harvested as a silage (Powell and Wing, 1967) the digestibility of the protein was 59 and 56% in two experiments. Nitrogen can become bound to the fiber fraction as a result of the heat of fermentation. This N will be unavailable to the animal and result in a lower protein digestibility.

In conclusion, fresh kenaf leaf-stem portions is readily consumed by growing lambs and contains a low concentration of fiber plus a high concentration of N. If we establish the value of crude protein at $0.55 per kg and the yield of crude protein as (total dry matter X 40% leaf-stem X 30% crude protein), then each kg of dry matter produced per ha would have a value of $0.067. A yield of 10,000 kg of dry matter per ha would yield a product worth $660. As yield increases gross return per land unit would increase. Also as the harvesting frequency increases the yield may decrease, but the percent crude protein could increase to offset the lost dry matter yield.

If kenaf were grown for fiber production, then the only product remaining for on-the-farm use as a feed would be the tops which are not used for pulp. These tops could be harvested and used as ruminant feed to increase the productivity of the kenaf operation and to decrease the cost of the associated with the animal enterprise. Mature kenaf tops contained the following amounts of NDF and ADF; 59.56% and 44.67%, 53.74% and 39.90%, and 55.02% and 40.34% for Everglade 41, Everglade 71 and C2032, respectively. The NDF and ADF concentrations in the mature tops was slightly higher than the values observed for the stalk portion of the fresh immature kenaf plant. The tops used in the present study had lost most of the leaf material prior to harvesting.

Adding kenaf tops to the basal diet did not alter dry matter intake (Table 3). The diet containing 10% Everglade 41 tops had similar digestion coefficients as the basal diet (Table 3). Adding tops from Everglade 71 and C2032 varieties significantly decreased NDF and ADF digestibility of the

total diet. Some dietary ingredients not only have low digestibility, but also exert a negative influence on the digestibility of the other ingredients in the diet.

Although nitrogen digestibility was not affected by treatment, nitrogen retention was lower (P.01) in the two diets with Everglade 71 and C2032 tops than the basal diet and basal diet plus tops from Everglade 41. Nitrogen retention is used to express the amount of nitrogen actually retained as body mass by the animal. Apparently the reduction in digestibility of the NDF and ADF fractions in the diets with Everglade 71 and C2032 tops reduced available energy for microbial protein synthesis and lower the amount of nitrogen retained by the lambs receiving those diets.

From Experiment 2 it can be concluded that mature kenaf tops could be harvested at the same time as the mature cane is being cut for pulp, but the quality of the tops are much lower than the quality of the fresh immature plant leaf-stem portion. If harvesting could be done before the leaves drop from the plant quality of the top portion would be much higher. The value of kenaf tops is similar to that of medium quality hay with a market value of approximately $0.06 per kg of dry matter.

In summary, kenaf affords the opportunity to cultivate a small area to produce high quality forage for supplementation of ruminant diets and a potential source of medium quality forage if the tops of the mature plant are harvested. Using kenaf as a feed source for ruminants may increase its acceptability to producers in the Southern Great Plains and create a reserve of kenaf production for the pulp industry to build on as demand for the plant as a fiber source increases.

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Irrigation Of Kenaf In A Desert

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During this past year E 41 kenaf plots planted in five monthly intervals from March to July were harvested at monthly intervals from September to November. Irrigation was based on ETo (potential evapotranspiration) calculated with a modified Penman equation over a low grass ground cover as recorded by the CIMIS program (California Irrigation Management Information System). Irrigation treatments consisted of water equivalent to 1.0, 1.15 and 1.3 times ETo applied by sprinkler. In the field trials planted in five monthly intervals seed from the same seed lot was planted with the same equipment. The five different planting dates were 21 March, 18 April, 24 May, 20 June and 18 July and the three dates of harvest were 19 September, 17 October, and 14 November.

Results

Although planted with the same seed and drill a significant increase in stand density occurred with each successive planting as shown in table 1. Data presented in table 1 shows the range of soil temperature on the date of planting, the stand one month after planting and the stand at harvest. We believe the stand as measured two weeks after planting reflects the soil temperature which was increasing during the period of planting. The stand density at harvest was lower than that measured at the start of the experiment reflecting the loss during the period of growth. This loss declined with each successive planting. The net result was a more than two fold difference in stand density between the first and last plantings.

TABLE 1. Soil temperature range on date of planting, and stand in kenaf at five planting dates. Drilled in 17.78 cm rows.

Planting Month	Temperature Range C	Stand at one Month plants/m2	Stand at harvest plants/m2
March	18 - 27	42.8a	24.3 a
April	21 - 28	46.5 ab	36.7 b
May	28 - 36	51.6 bc	49.9 c
June	31 - 36	53.6 c	53.5 c
July	36 - 38	76.9 d	69.3 d
LSD 5%		6.6	5.4

As in last year's work the highest irrigation treatment produced the highest yield. In 1987 the high rate received 186 cm (1.25 ETo) in 1988 the highest was 202 cm (1.30 ETo). The lowest treatment rates were 0.75 ETo in 1987 and 1.0 ETo in 1988. In the 1988 trial application rates ranged from 35cm for the last-planted-first-harvested to 202 cm for the first-planted-last-harvested plots. Yield response to water quantity and stand was analyzed by multiple linear correlation. This produced a statement showing the significant effect of both water quantity and stand as follows:

Yield = 0.083653 W + 0.035343 D - 0.8971
Yield in t/ha, W = cm water, D = plants/m2 n=405, R^2= 0.439
Standard Error = 3.295, Fisher F = 157, Probability = .000

A segregation of yield components of the averages of the three irrigation, five plantings and three harvests into stalks, leaves, dead stalks and seed pods is shown in table 2.

Table 2. Yield of kenaf from an experiment with three irrigation treatments, five planting dates, and three harvest dates.

Treatment	Total Dry Weight	Stalk Dry Weight	Leaf Dry Weight	Dead Dry Weight	Pod Dry Weight
	t/ha	t/ha	t/ha	t/ha	t/ha
Irrigation	*	*	**	ns	ns
Wet	14.49	11.85	1.95	.272	.449
Inter	13.56	10.89	1.96	.300	.447
Dry	13.79	10.79	2.44	.160	.432
Plant Date	**	*	**	**	*
March 21	17.02	14.02	2.31	.370	.337
April 18	16.27	13.34	2.06	.508	.395
May 24	15.89	12.82	2.30	.269	.541
June 20	10.84	08.62	2.68	.073	.498
July 18	09.73	07.09	2.22	.000	.442
Harvest	**	**	**	**	**
Sept. 19	12.28	09.56	2.61	.115	.000
Oct. 17	14.36	11.20	2.74	.261	.181
Nov. 14	15.20	12.77	0.99	.356	1.147

Conclusions

From the germination data it is apparent that in a commercial kenaf industry in California higher seeding rates should be considered for the earlier months of March and April than for later plantings.

The irrigation data indicate that kenaf responds well to high irrigation levels.

In Southern California the late March planting produced the highest yield. Each successive harvest date produced a higher yield of stalk dry weight.The November harvest also had a significant increase ease in pod production. If it is desirable to avoid seed pods in the harvest, it would be better to harvest by the end of October.

In a second experiment ten lines of kenaf were grown in four replicates of a randomized complete block design from 1986 until 1988. Yields in tons/ha and tons /acre of dry weight in stalks are shown in Table 3. Plants were grown with furrow irrigation.

TABLE 3. Yield of stalk dry weight

Kenaf Line	t/ha	T/A
E-41	20.86 +/- 2.00 a	9.31 +/- 0.89 a
Xiang	20.70 +/- 2.38 a	9.24 +/- 1.06 a
45-9x	20.07 +/- 1.91 a	8.96 +/- 0.85 a
C-108	19.40 +/- 1.65 ab	8.66 +/- 0.74 ab
7818-RS 10	19.07 +/- 1.75 abc	8.51 +/- 0.78 abc
E-71	18.04 +/- 1.51 bc	8.05 +/- 0.67 bc
Cv-34	17.82 +/- 1.83 c	7.96 +/- 0.62 c
Tainung	17.72 +/- 1.61 cd	7.91a +/- 0.72 cd
G-45	15.89 +/- 1.41 d	7.09 +/- 0.63 d
C-2032	13.87 +/- 1.54 e	6.19 +/- 0.69 e
LSD 5%	1.91	0.86

The kenaf comparisons have identified a group of five kenaf lines that could provide a beginning industry in the Southern California desert area. The yields in the first experiment are lower because they are averages of the two other treatments, i.e., the last harvest yield for 14 November in table 2 is an average of all irrigation treatments and all planting dates. It has been noted however, that yields are generally lower under the sprinkler irrigation than in furrow irrigation. This may be due to the lower temperatures resulting from the evaporation of the sprinkler water from the plant surfaces during and after irrigation.

Plans For Next Year

In 1990 we would like to examine the regenerative capability of the kenaf. The high protein content of the leaves suggests that it could be a good forage crop if it could be cut and regrown without replanting. We would also like to continue to explore methods of seed production.

Plant Population Density and Dates Of Harvest on Kenaf Fiber Production in the Lower Rio Grande Valley Of Texas

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Abstract

The response of "Everglades 41" kenaf (*Hibiscus cannabinus L.)* to different plant population densities were investigated in 1986 and 1988 in Monte Alto, Texas. The objective of the study was to determine an optimal planting density of kenaf to produce highest yields of fiber for use in newsprint paper. Results from this study indicate, that when kenaf is grown using a double row (2 rows10"apart) culture on 40 inch beds, high initial plant population densities do not result in improved dry matter yields. Under conditions of this study, there appears to be no advantage in exceeding initial plant population densities of 100,000 plants/acre. The optimal initial plant population density appears to be from 74,000 to 108,000 plants/acre for "Everglades 41" kenaf. This translates to a recommended seeding rate of 7.1 to 10.4 lbs seed/acre for this variety.

Introduction

Investigations with kenaf (*Hibiscus cannabinus L.*) began at Rio Farms, Inc. in the spring of 1949. During this time there was a national interest in developing an acceptable substitute for jute fiber, therefore kenaf received considerable research attention. Most of the previous kenaf research had been conducted by the USDA in Florida; However, Rio Farms, Inc. staff obtained seed from Cuba and grew both seed and fiber crops of kenaf in the Lower Rio Grande Valley of Texas. Synthetic fiber production reduced the demand for natural fiber alternatives, and research with kenaf was suspended.

Some 32 years after those initial investigations with the crop, Rio Farms, Inc. once again became involved with kenaf research. The emphasis of utilization had shifted toward kenaf as a raw material in the making of newsprint paper. Working since 1981 with Kenaf International and the USDA, Rio Farms, Inc. has conducted applied research studies on kenaf for both seed and fiber production. One area of this applied work focused on plant population density, which translates to grower seeding rates.

In an early "how to grow kenaf" paper, Walker (1951) suggested that rows should be 6 to 8 inches apart when kenaf is grown for fiber and 6 to 20 inches apart when planted for seed. He did not recommend broadcast planting. Stem yields have been reported to generally increase with increasing plant densities, Williams (1966), Wilson and Joyner (1969), Higgins and White (1970),

White et al. (1971), and Bhangoo et al. (1986). Massey (1974) reported an increase in stem yield of "Everglades 71" from 4.37 to 5.17 tons when row spacing was decreased from 28 to 14 inches. Plant population densities went from 75,000 to 150,000 plants per acre. Narrow row spacings (8 and 12 inches) and plant population densities of 101,250 and 202,500 plants per acre were reported in a Sudan study by Salik (1978) to produce the highest stem production.

Significant stand reduction from plant mortality at high plant population densities has been reported by Higgins and White (1970), White et al. (1971) and Campbell and White (1982). In general, the higher the plant population density the greater the percent stand reduction. Campbell and White (1982) reported a 50 percent stand reduction at the highest density.

Contrary to these findings are those of Killinger (1965) who in Florida found enhanced yields of 27,511 to 47,276 plants per acre on 38 inch rows over that of 19 inch rows. Williams (1966) reported no significant difference in yields at various plant population densities of nonirrigated kenaf over 5 years in Nebraska. Some varieties, such as "Cubano", were noted to yield well at very low plant population densities (White (1969) (1970).

Investigations designed to compare fiber production of kenaf grown at different plant population densities were conducted in 1986 and 1988 at Monte Alto, Texas. The objective of the study was to determine an optimal planting density for kenaf to produce the highest yields of fiber for use in newsprint paper production. Also included in the study was evaluation of date of harvest on kenaf yield.

Materials and Methods

Kenaf variety "Everglades 41" was planted on 18 April 1986 and 8 April 1988 in a Hidalgo sandy clay loam soil. The row culture used was two rows 10 inches apart on 40 inch center beds. This row culture is commonly used by growers in the area and was compatible to the harvesting equipment under development for kenaf.

Plant population densities of 296,000, 148,000, 99,000, and 74,000 plants/acre were achieved by hand thinning over planted plots 24 days after planting in 1986. Plant population densities of 263,200, 169,500, 107,600, 81,700, 49,400, and 21,700 were achieved by hand thinning over planted plots 25 days after planting in 1988. The experimental design was a randomized complete block with five replications both years. Plot size was 8 beds wide 50 feet long.

The fertilizer program in 1986 consisted of 16 gal 10-34-0/acre applied preplant in one band in the center of each bed. In early May, a sidedress application of N-32 was applied at the rate of 20 gal/acre. net fertilization was 88 lbs N and 60 lbs p_2o_5/acre. In 1988, 33.9 gal N-32/acre was sidedressed 29 April for a net fertilization of 120 lbs N/acre. In early March, 6.5 Gal Telone II/acre was applied to the 1988 study for soil fumigation.

The herbicide program consisted of Prowl applied broadcast ppi at 1 pt/acre and 1.5 Pt Dual/acre applied PES in 1986 and 1988 respectively. The 1986 study was cultivated twice with a Lilliston rolling cultivator and irrigated once during the growing season. The rainfall received totaled 18.91 inches up to the September harvest and 19.67 inches up to the October harvest. The 1988 study

was cultivated twice with a Lilliston rolling cultivator and irrigated 3 times during the growing season. The rainfall received totaled 9.51 inches up to the September harvest and 12.70 inches up to the October harvest.

All harvests (22 Sept. 86, 17 Oct. 86, 6 Sept. 88, 18 Oct 88, 8 Dec. 88) were made using the same methodology. Plants in 13.1 feet of the center beds of each plot were harvested by hand using a gasoline powered brush cutter. All plants were cut a uniform 2 inch distance from the soil surface. Plants were allowed to dry in an open area of the field for 2 to 3 weeks at which time total sample weights from each plot were determined. Estimates of percent moisture were made for each plot using 2 subsamples of 12-15 randomly selected plants. For each subsample, 6 inch sections from the upper, middle and lower 1/3 of each plant were cut, weighed and oven-dried for 48 hours at 60 C. Differences in dry and wet weights were used to calculate percentage moisture estimates which were used to convert green plot weight to lbs dry matter (DM)/acre. Following the last harvest in 1986, the final population density of each plot was determined.

In the 1988 study, the number of plants from each harvested plot area was taken. From this, average stalk weights were determined. Two 13.1 feet bed areas were marked in each plot and plant height data were collected at 45, 60, 77, 153, and 193 days after planting.

Results

No differences in dry matter yield of kenaf due to plant population density was observed for either the September or October 1986 harvest dates, Table 1. In 1988 the plant population densities ranging from 263,200 to 81,700 plants/acre, Table 2, were consistent with the 1986 data. No differences in dry matter yield of kenaf due to plant population density were observed in 1986 and 1988. However, in the 6 Sept 88 harvest the 21,700 plants/acre density yielded significantly less than the 4 highest densities.

There was no significant difference in DM yield between plant population densities in the 18 Oct 88 and 8 Dec. 88 harvests. When the plant population data for all harvest was pooled the 107,600 plant population density DM yield of 7.16 tons/acre was significantly higher than that of 49,400 and 21,700 plants/acre.

There was no significant difference in yield due to harvest date in the 1986 study. However, the 6 Sept. 88 harvest was significantly less than the 18 Oct 88 and 8 Dec. 88 harvests. Mean yields of October harvest in 1986 and 1988 were similar (6.79 and 7.11 tons DM/acre respectively.

There were dramatic decreases in plant numbers, particularly when initial densities were high in both studies. In May 1986, plant population densities ranged from 74,000 to 296,000 plant/acre, but by October this range was reduced to 61,750 to 82,750 plant/acre. This translates to 16.6 to 72% stand reduction due to plant mortality.

Table 1. Plantpopulation density and date of harvest effects on mean dry matter yield of "Everglades 41" kenaf planted 18 April 1986 in the Lower Rio Grande Valley.

Yield (ton DM/acre) [a,b]					
Initial	Date of Harvest [c]			Final	
Popl. Density				Popl. Density	% Stand
30 April	22 Sept	17 Oct	Average	17 Oct	Reduction
296,000	6.89	6.64	6.77	82,750	72.0
148,000	6.80	6.01	6.41	79,950	46.0
99,000	7.09	7.46	7.28	64,500	34.9
Average	7.01	6.79			

a/ DM = dry matter

b/ There were no statistically significant differences in yields due to Population Density, Date of Harvest or Population X Date of Harvest interactions.

c/ CV=24.0%

Table 2. Plant population density and date of harvest effects on mean drymatter yield of "Everglades 41" planted 8 April 1988 in the Lower Rio Grand Valley of Texas.

	Yield (tons DM/acre [1/]				
Initial	Date of Harvest				
Popl. Density					Final
3 May	6 Sept	18 Oct	8 Dec	Average	Popl. Density
263,000	6.45 a	7.41	6.81	6.89 ab	81,000
169,500	5.95 a	7.45	6.47	6.62 abc	74,100
107.600	6.38 a	7.82	7.29	7.16 a	58,900
81,700	6.41 a	7.11	7.42	6.98 ab	49,500
49,400	5.62 ab	6.77	6.17	6.18 bc	33,500
21,700	5.21 b	6.12	6.40	5.91 c	21,400
Average	6.00 b	7.11 a	6.75 a		

1/ Yields followed by the same letter are not significantly different using LSD .05.
CV = 16.8%

The 1988 study produced findings in support of the 1986 study. In areas marked early to study percentage stand reduction, the stand reductions were dramatic, Table 3. The percentage stand reduction is directly related to initial plant population density. The higher the initial plant population density the greater the percentage stand reduction. This ranged from a low of 0.5% at 21,700 plants/acre to a high of 61.8% at 263,200 plants/acre.

Table 3. Percentage stand reduction from 26 to 177 days after planting (DAP) of 6 plant population densities of "Everglades 41" kenaf planted 8 April 1988.

Plant Population Density		
26 DAP	177 DAP	% Stand Reduction
263,200	100,600	61.8
169,500	86,500	49.0
107,600	59,200	45.0
81,700	53,300	34.8
49,400	39,300	20.5
21,700	21,600	0.5

There exists a direct relationship to plant population density and average stalk weight, Table 4. The higher the plant population density the less the average stalk weight. In the 18 Oct 88 harvest, average stalk weights ranged from a high of 0.57 lbs/stalk at 21,400 plants/acre to a low of 0.18 at 81,000 plants per acre at harvest. Plant height data are presented in Table 5. At 45 days after planting (DAP) the higher the plant population density the taller the plants. At 60 DAP only the lowest density (21,700 Plants/acre) is significantly less than the others. From 77 DAP on, there is no significant difference in plant height at all plant population densities.

Table 4. Average weight per stalk of 6 plant population densities on the 18 October 1988 harvest of "Everglades 41" kenaf planted 8 April 1988.

Plant Population Density at Harvest	Average Weight lbs/Stalk
81,000	0.18
74,100	0.20
58,900	0.27
49,500	0.29
33,500	0.40
21,400	0.57

No differences in dry matter kenaf yield due to plant population densities in the range of 296,000 to 74,000 plants/acrewere observed in September or October harvests in 1986 and September, October, or December harvests in 1988. Yields approached 7 tons dry matter/acre. Yield from 21,700 plants/acre density were less than the 4 highest densities. In 1986 there was no difference in date of harvest yields; however, the September harvest yield was less than the October and December harvest yields in 1988. Dramatic reductions in stand were observed in the higher plant population densities. The higher the plant population density the greater the stand reduction, reaching a high of 61.8% at 263,200 plants/acre. A direct relationship between plant population density and average stalk weight was observed. The higher the density the less the average stalk weight. Forty five days after planting the higher the plant population density produced,the taller the plants. Seventy-seven days after planting until harvest there is no difference in plant heights.

The optimal plant population density appears to be from 74,000 to 108,000 plants/acre for"Everglades 41" kenaf and a seeding rate 7.1 to 10.4 lbs seed/acre is recommended.

Table 5. Plant heights of "Everglades 41" kenaf at 6 plant population densities at 45, 60, 77, 153, 193 days after planting (DAP).

Plant Population	Plant Height (inches) 1/				
Density	45 DAP	60 DAP	77 DAP	153 DAP	193 DAP
263,200	39.9 a	59.6 a	85.1	147.2	154.4
169,500	38.2 ab	61.3 a	84.3	144.2	149.8
107,600	35.6 bc	57.9 a	81.7	151.6	159.6
81,700	34.6 cd	57.6 a	84.1	148.8	162.6
49,400	32.3 d	55.7 a	82.6	140.4	154.6
21,700	29.1 e	49.5 b	73.4	142.6	156.6
Average	35.0	56.9	81.9	145.8	156.3

1/ Heights followed by the same letter are not significantly different using LSD 1050 77 DAP, 153 DAP, and 193 DAP heights were not significantly different.

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A Proposed Method To Simplify Kenaf Stem Dry Weight Yield Determinations

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ABSTRACT

Harvesting, drying and storing kenaf from yield plots are labor-intensive operations. Also, there appears to be no standardized moisture content in reporting yield; neither is there a standard procedure for drying plant material. Scientists studying kenaf face handling problems due to the crop's sheer bulk. The objective of the present study was to develop a simplified and reliable method of determining stem dry matter yield for field-grown kenaf that reduces the extensive handling problems associated with the crop. It was theorized that actively growing plants of a given age and variety within a uniform plant population should have similar dry weight to fresh weight ratios. Environmental conditions may influence this ratio, but individual plants within the population should react similarly to environmental changes. Kenaf varieties 'Everglades 41' (E41) and 'Everglades 71' (E71) were planted in a silt loam soil at the Texas Agricultural Experiment Station in Beaumont, Texas, as entries in a planting date/variety trial study. Kenaf variety 'Cubano' was planted in a fertility study where fertilizer levels varied from 0-0-0 to 250-5O-50 lb N,P_2,O_5,K_2,O/A. Two or three plants of E41 and E71 from the planting date/variety trials and Cubano from the 0-0-0 and 200-50-50 fertility plots were harvested at selected times during the growing season. Total plant fresh weight and stem dry weight (oven-dry basis) were determined. The stem dry weight to total plant fresh weight ratios were developed for each harvest date. In four out of five comparisons, the results from this method (termed the coefficient method of yield determination) compared favorably to the ratio developed from weighing and drying an entire plant bundle from a 16-foot harvested row. Early results appear promising and may offer a simplified method of determining kenaf stem dry matter yields.

Kenaf (*Hibiscus cannabinus)* is a non-food, fiber crop which can be used in the manufacture of paper and as a substitute or extender for other woodbased products. It is generally accepted that U.S. commercial production " kenaf would be restricted to the southern U. S. due to the longer growing season. Once established, kenaf is a vigorous plant, reaching a height of over 12 feet in five months (1, 2). Insects and diseases on kenaf have not been problems in Southeast Texas.

Although stems are discarded during the harvest of most crops, they are the object of kenaf harvest. Scientists who experiment with kenaf face harvesting, storing, and drying problems due to the crop's sheer bulk. Usually 10 to 20 plants are subsampled from a plot to determine dry-stem

weight. There appears to be no standardized moisture content in reporting stem yield; neither is there a standard procedure for drying plant material. Lack of a standardized method for reporting kenaf stem yield could result in inaccurate comparisons or conclusions among experiments performed by various research scientists.

Harvesting, drying, and storing bundles of kenaf for individual plot yield estimates are labor-intensive operations. The bulky material can present drying, weighing, and storage problems. Past experience has shown that even after 4- to 6 weeks of natural air-drying, individual stems within the bundle have highly variable moisture contents, making accurate yield determinations difficult. It is theorized that actively growing plants of a given age and variety within a uniform plant population should have similar dry weight to fresh weight ratios. Environmental conditions may influence this ratio, but individual plants within the population should react similarly to these environmental changes. It was upon this premise that the present study was initiated to develop a simplified and reliable method of determining stem dry matter yield for field-grown kenaf.

Methods And Materials

Six varieties and three planting dates were utilized in a variety and planting-date study at Beaumont. A twelve-treatment fertility study using the Cubano variety was also conducted at the Beaumont Center. The information herein reported was derived from these two studies. Agronomic and cultural information are presented in Table 1.

Stem dry weight to total plant fresh weight ratios were established for two varieties, 'Everglades 41' (E41) and 'Everglades 71' (E71). This was done by randomly sampling two to three average plants from one row of a 2-row plot from the variety trials once per week during the four weeks prior to harvest. The plants were quickly weighed to determine their fresh weight, leaves removed, and the stems dried in a forced air oven at 217^{o} F for two hours, followed by 158^{o} F for a minimum of 24 hours. Stems were then cooled to room temperature, weighed, and the stem dry weight to total plant fresh weight ratio determined. The stem dry weight to total fresh weight ratio of an entire bundle from a 16-foot harvested row was also determined for selected plots and compared to the stem dry weight to total fresh weight ratio developed from the small plant sample. A similar procedure was used for a high and low fertility plot from the fertilizer study. However, stem dry weight to total fresh weight ratios were based on a two-plant sample.

Results And Discussion

Dry stem weight to total plant fresh weight ratios of E41 and E71 from the three planting dates were determined (Fig 1). Since the ratios for both varieties were constant and nearly identical throughout the 4-week period prior to final plot harvest, the values (with standard errors) in Figure 1 are averages of the four, weekly determinations. For the first two planting dates, the ratios of the two varieties were rather constant and similar. Plants from the third planting date were the youngest and had the lowest stem dry weight to total plant fresh weight ratio. As indicated by the standard errors, the variability among the four sampling times was small with little to no change in the ratios during the 4-week sampling period near the end of the growing season.

Table 1. Agronomic and cultural information on Kenaf studies at the Texas Agricultural Experiment Station, 1988.

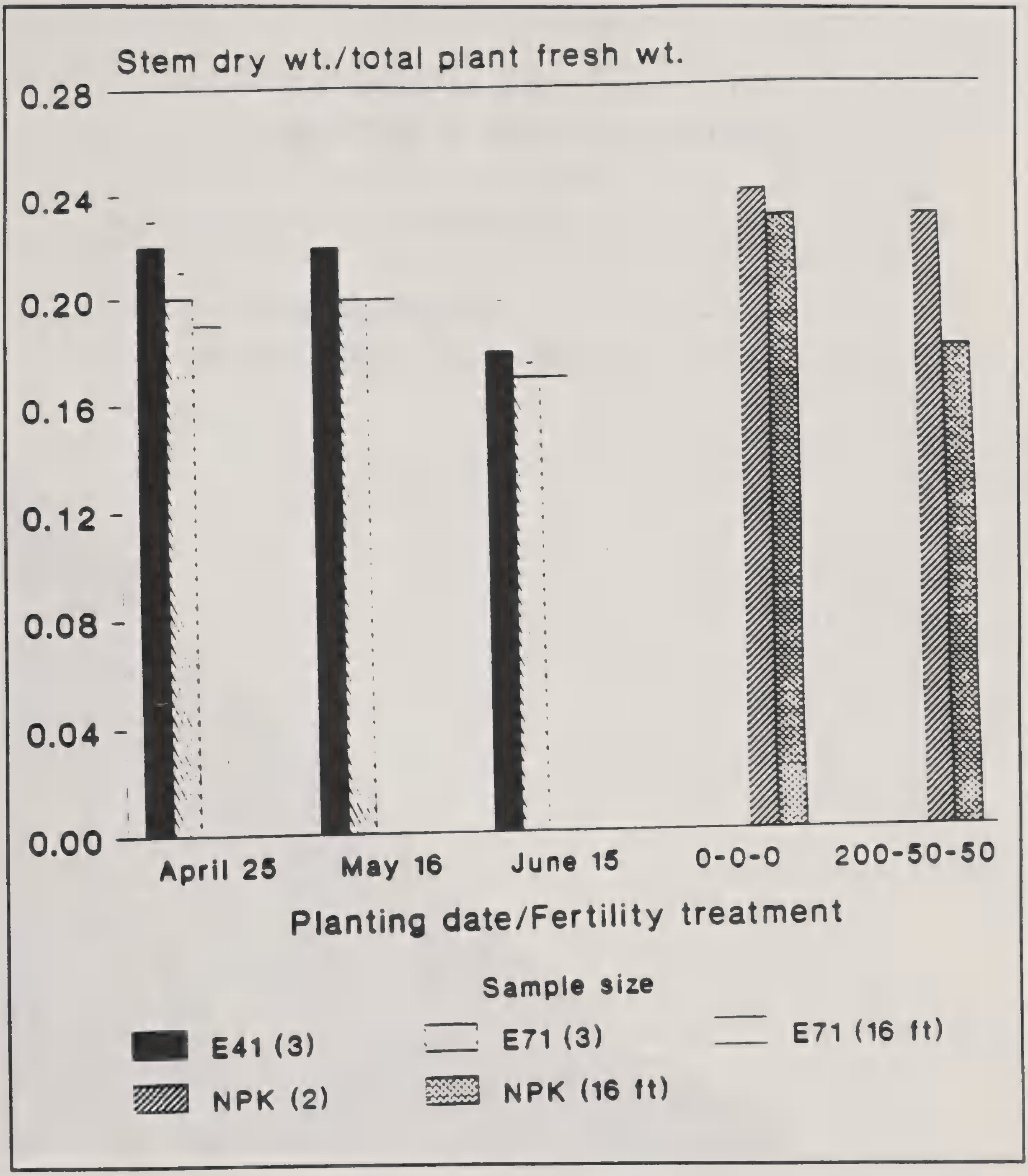
VARIETY TRIAL/PLANTING DATE STUDY

Location:	Beaumont
Soil type:	Bernard-Morey complex
Previous crop:	fallow
Plot size:	2 rows, 32" x 20'
Number replications:	4
Harvest date:	October 18
Size harvested plot:	0.001 acres
<u>First Planting Date:</u>	April 25
Herbicide:	2.0 pt/A Dual 8E on April 26
Fertilizer:	0-30-100 on April 20 150-0-0 on June 8 (lbs N, P_2O_5, K_2O per A)
<u>Second Planting Date:</u>	May 16
Herbicide:	2 pt/A Dual 8E on May 16
Fertilizer:	0-30-100 on April 20 150-0-0 on June 22 (lbs N, P_2O_5, K_2O per A)
<u>Third Planting Date:</u>	June 15
Herbicide:	2 pt/A Dual 8E on June 15
Fertilizer:	0-30-100 on April 20 150-0-0 on July 11 (lbs N, P_2O_5, K_2O per A)

FERTILIZER RESPONSE STUDY

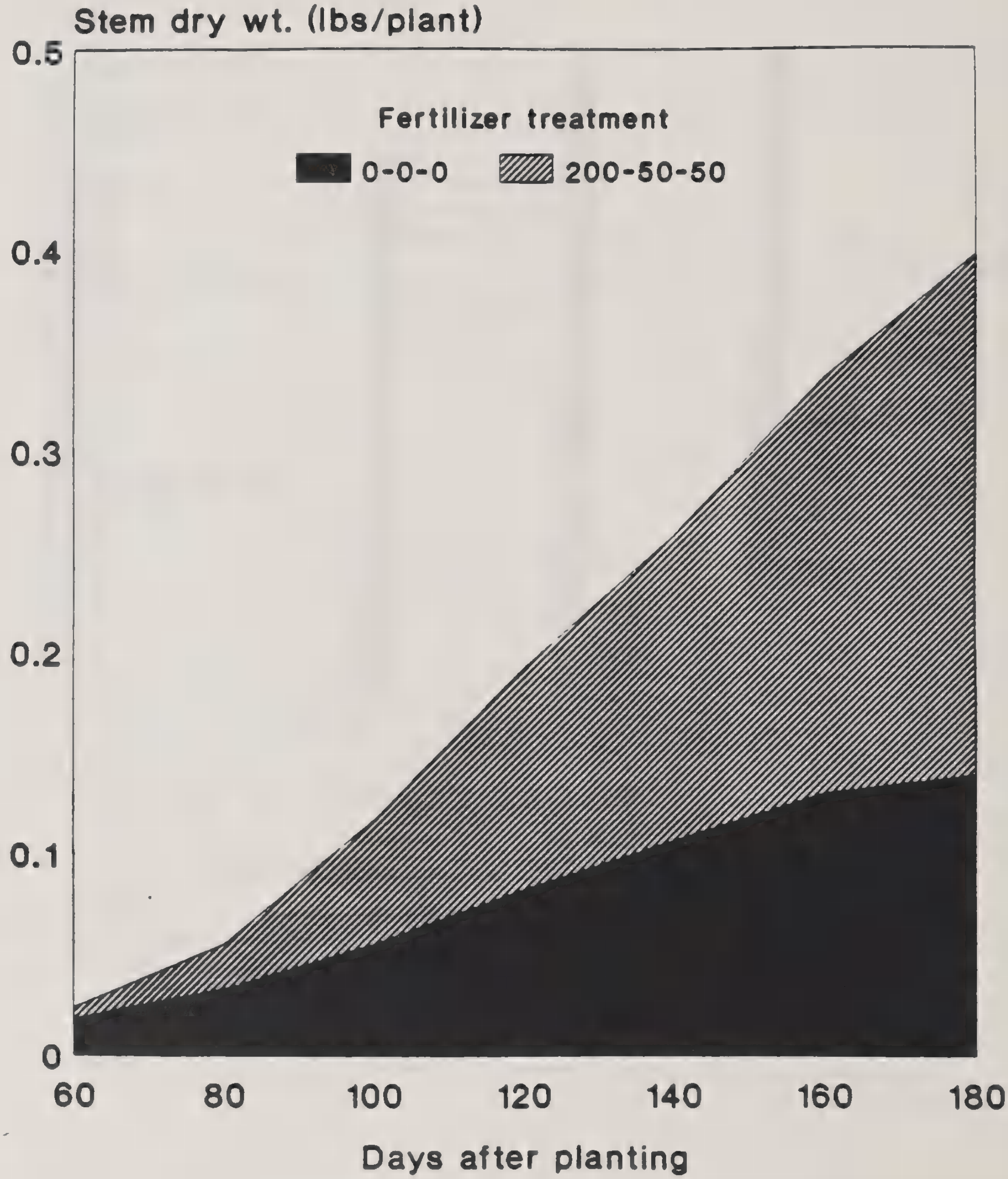
Planting date:	April 19
Soil type:	Bernard-Morey complex
Previous crop:	fallow
Plot size:	4 rows, 32" x 20'
Number replications:	3
Herbicide:	2 pt/A Dual 8E on April 19
Fertilizer:	variable
Harvest date:	October 18
Size harvested plot:	0.001 acres

Fig. 1 . Results from sampling procedures to determine yield coefficient for kenaf (2-3 plants versus a 16 ft. row).



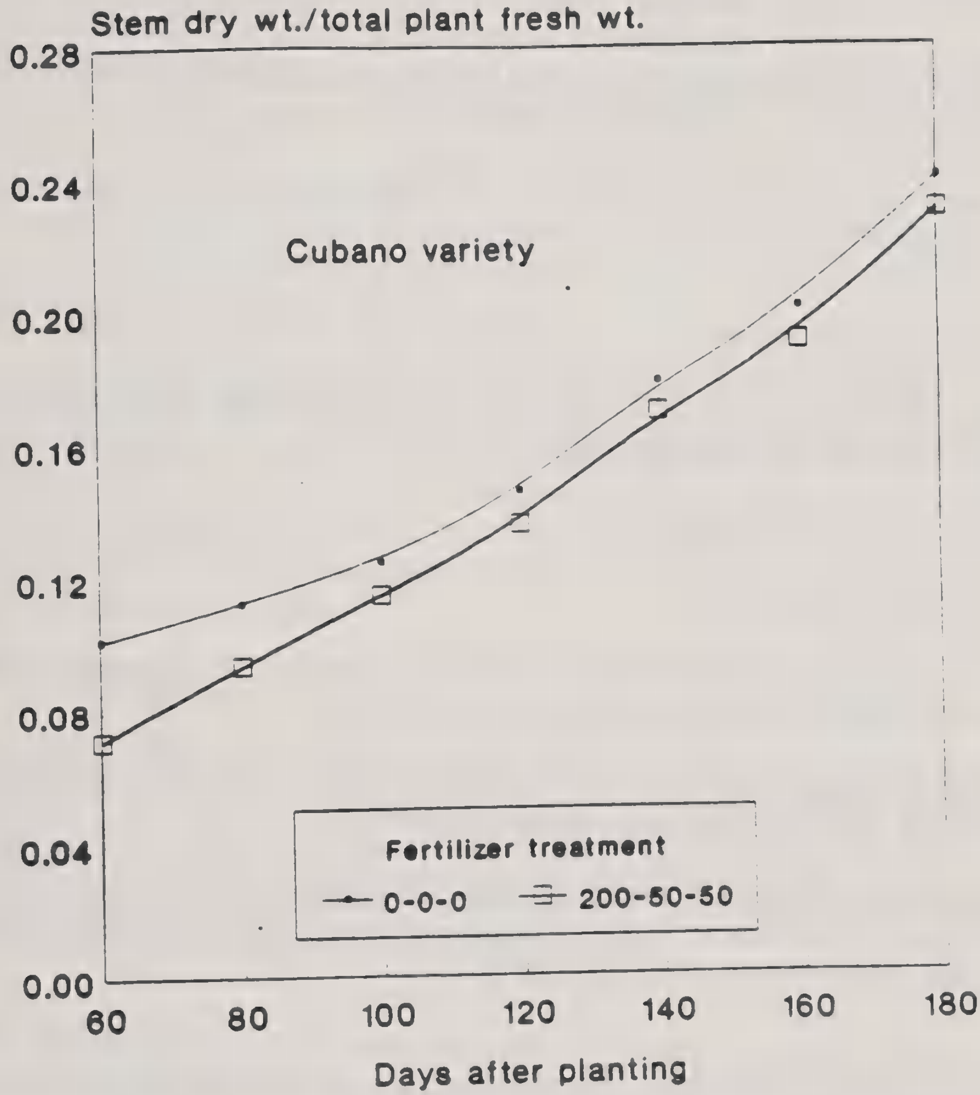
Kenaf showed remarkable response to added fertilizer (Fig 2). Stem dry weight per plant was nearly 3-fold higher in the high fertility plot compared to the zero fertility plot. Stem dry matter production peaked 170 days after planting (DAP) in the 0-0-0 plots but continued to increase through 180 DAP in the 200-50-50 plots.

Fig. 2. Response of kenaf stem dry matter production to fertilizer.



Even with the large difference in stem dry weights, the stem dry weight to total fresh weight ratios between plants from the two fertility treatments remained similar. The time-course of stem dry weight to total plant fresh weight ratios for the 0-0-0 and 200-50-50 plots is presented in Figure 3. The ratios from both fertility levels increased in parallel fashion, with the 0-0-0 ratio slightly greater than that from the 200-50-50 plots. Final ratios (Fig. 2) were 0.24 for the 0-0-0 plots and 0.23 for the 200-50-50 plots, and similar to those recorded from the early planting of two varieties in the variety trials (i.e. 0.20 and 0.22 for E71 and E41, respectively).

Fig. 3. Ratio of kenaf stem dry wt. to total plant fresh wt. over time in two fertility treatments.



The method of sampling several plants and determining their average stem dry weight to total plant fresh weight ratio (hereafter referred to as the coefficient method) was compared to the ratio (average of two replications) generated by the total number of plants from a 16-foot harvested plot. The results presented in Figure 1 show that the coefficient method has potential for determining plot yields with an acceptable degree of accuracy, with ratios similar in 4 of the 5 comparisons. Only the ratio generated from the entire bundle of the 200-50-50 fertility treatment did not compare favorably with the ratio derived from the coefficient method. It should be noted that only two plants from the fertility test were used for the coefficient method. Perhaps this number should be increased. Also, the actual bundle dry weights were not determined until two to three weeks after plot harvest due to a backlog of other field work. This may have introduced some error.

In practice, fresh bundle weights at harvest could be recorded in the field and later multiplied by the stem dry weight to total fresh weight coefficient generated from a recent harvest of a few plants within the yield plots. Research is currently under way to refine this coefficient method and identify its limitations. However, early results appear promising and may offer a simplified method for determining kenaf stem dry matter yields.

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New Crops + New Technologies + New Markets A System Approach Equals New Opportunities For U.S. Farmers

By

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One should avoid the temptation to present a paper in its title. However, a close association over the past few years with some of the nation's leading publishers has made me aware of the importance of headlines. This brief paper seeks to describe some of the opportunities that do exist for U.S. farmers and industry and outline an approach that can bring such potentials to fruition without draining the national treasury.

This paper can be viewed as an unsolicited response to recent initiatives of the U.S. Congress such as House Bill #1197, "National Institute for New Agricultural and Forestry Industrial Materials Act" and Senate Bill #970, "Alternative Agricultural Products Research Act". Both bills identify the need to do "something new" in agriculture, but essentially prescribe old remedies, i.e., more bureaucracy and tax dollars. Although there is a time and place for everything, I am increasingly convinced that too much dependence on public policy and public institutions is not healthy for agriculture. It is not good business.

In 1985, Dr. Blase of the University of Missouri presented testimony before the Joint Economic Committee of Congress in which he addressed the need for a systems approach in the introduction of new crops (1). This paper borrows from that presentation and emphasizes the following points. First, the economic rationale for new crop technologies is presented. Second, the potential uses of the Production-Marketing Consumption (PMC) System for strategy formulation are described. Third, a public-private cooperative model to introduce a new crop system is discussed and illustrated by current work with kenaf.

The Economic Rationale

From my perspective as an agricultural economist, there are three primary factors that justify efforts to further the introduction and establishment of new crops in agriculture. The first is the excess capacity currently plaguing the U.S. farming sector. Next is the inefficient way in which resources are spent by public institutions to develop and introduce new crops. Then there is the potential contribution to economic development of new crop based agro-industries, including consideration of present trade deficits. Each deserves elaboration.

Excess Capacity

The United States has been blest with more agricultural resources than currently required by present technologies to meet domestic and export demands for traditional foods and fibers. The

need to better utilize this "excess" capacity represents one rationale for directing more efforts and resources to the development of new crops.

The Center for National Food and Agricultural Policy specified in its 1984 ten-year forecast for the agricultural sector that approximately 26 to 30 million excess acres exist, given present cropping alternatives and acceptable rates of return to resources (2).

Excess capacity in agriculture is generally defined in terms of idled or under utilized land. It also has been referred to as production in excess of demand. Clearly, excess capacity involves under and/or economically inappropriate utilization of equipment, manpower, and other resources. Regardless of the terms of reference employed, almost any review of the current farming situation will confirm that substantial resources could be shifted to the production, processing, and marketing of new crops if they could be identified in terms of a system and acted upon by system participants.

Inefficiencies

Efforts to introduce new economic opportunities for U.S. farmers have been beset by seemingly inherent inefficiencies. At best,new crop establishment can be described as disjointed, unorganized, and inefficient. Although no empirical estimates have been formulated to adequately document the extent of this inefficiency, there is little doubt of its existence and costly impact on the nation's farm economy.

Consider the likely phases or hurdles through which the introduction of a hypothetical new crop progresses -- based on the historical experience of past "new crops". Initially, the wild plant is located in some other part of the world and is brought to the United States for experimental growing and observation. Perhaps due to some specific characteristic (e.g., fiber, oils, nutritional value, etc.) that is deemed interesting, a geneticist works with the plant and, perhaps, even encourages a small number of farmers to try growing it under semi-commercial conditions. Other agricultural disciplines may also become involved in advancing the plant from curiosity to field testing. However, often this comes to naught because, among other things, no markets may exist. . .they have to be created.

Decades can elapse during which this particular crop candidate is essentially forgotten, certainly in terms of actual production and utilization. Inevitably, when placed on the back burner in the agricultural sector, a potential industrial user may perceive the need for a product similar to what this plant can produce and, upon scanning the literature, determines that the plant in question exists. After learning what had been done earlier with the plant, perhaps an effort is made via contract growing to have some of the crop grown for the private firm.

Very frequently, these pioneering efforts run aground as the investment in agriculture to produce sufficient material for thorough testing overextends available risk capital. Attempts to secure the required product development capital often turns new crop entrepreneurs into full-time promoters, sidetracking their energies and soiling their credibility, especially if they fall into compromises with shortsighted politicians. Experimenting farmers will often encounter such field problems as disease outbreaks, insect attacks, and unsuitable equipment (especially, harvesting), because

little to no work has been done in the disciplines of pathology, entomology, and agricultural engineering to name a few examples. Regardless of the specific problem encountered, the new system suffers another setback and it's back to the barn.

And on the story goes -- sometimes for 200 years, as was required for that "pearl of the orient", the soybean, to become an established crop. In sum, the procedures now being used are highly discontinuous, quite haphazardly conducted, and, at minimum, make inefficient use of resources and time. Surely a country that has the management ability and resources to put a man on the moon, should have the capability to improve on its utilization of mother nature's vast cupboard.

One is tempted to pause here to underscore the philosophical fact that "there is nothing new under the sun" or moon by quoting Niccolo Machiavelli who must have had new crops in mind when he observed more than 450 years ago that "There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things."

A more recent observation was made by one of the author's partners, i.e., "A pioneer is someone who got too far out in front and picked up an ass full of arrows." I can attest from experience that often it's no fun to be a new crops pioneer.

Economic Development

A basic rationale for the establishment of a new crop system is the improvement in the standard of living that will result. In his classic work on the subject, Schumpeter identified several sources of growth (3). Included in these were new products and new methods of producing existing products. Both apply to the establishment of new crop systems.

The potential for supplying ingredients for new medicines from new crops is a fascinating illustration of the first potential for development. Another, perhaps more realistic, potential is the possibility of producing a nutritious snack food from new crops. For example, the combination of its popping ability and its exceptionally well balanced set of amino acids makes grain amaranth a candidate feedstock for a more nutritious group of snack foods than those presently on the market. While other illustrations could be given, the point is that our standard of living can be enhanced by new crops.

The second source of development, i.e., via new methods of producing existing products. Newsprint pulp, produced from the annual hibiscus plant kenaf with less energy than required when produced from wood fiber, illustrates this point. Likewise, the production of a substitute for sperm whale oil by harvesting the jojoba plant could enable society to accomplish some of its environmental and ecological objectives while not detracting from the accustomed standard of living. Clearly, one of the potential "engines" of the development process is the establishment of systems based on new crops.

Another aspect of economic development worthy of note concerns potential import substitution. Present balance of payment problems dictate that the United States would be well advised to use some of its excess agricultural resources to produce currently imported products. Again, using

kenaf as an illustration, the potential exists for reducing imports of newsprint, which currently represent about 60 percent of consumption and an annual import value of about $4 billion. Undoubtedly, the United States could attack some of its balance of trade problems with new crops such as kenaf.

The PMC Systems Approach as a Basis for Strategy Formulation

The author, with Dr. Blase, developed a decision matrix to evaluate the subsystems, e.g., production, marketing, and consumption, that make up a system for transferring a farm product from field through processing (packaging, etc.), and, finally to a consumer (4). In the PMC System Matrix, each of the systems is identified by component parts.

Three questions are asked of each system component. Is it physically possible to perform the function in question? If so, is it economically feasible to do so? and, finally, is it institutionally permissible to do so? All three questions for all of the functions must be answered in a positive fashion for a new crop system to be established. In most cases, there will exist several gaps and/or bottlenecks in the emerging system that need attention. Consequently, there is a need to formulate dynamic strategies to overcome obstacles, be they physical, economic, or institutional, to the establishment of the new crop's system.

A strategy is the process of following a time-phased sequence of predetermined activities, leading to a desired goal or outcome. That is to say, a "game plan" is formulated. Let us, consider how a strategy might develop for a given crop system.

Strategy Formulation

The first step is to consider whether each of the functions in the decision matrix is physically possible. There are several aspects of this question. Does the technology exist for performing the function required of each component? For example, are agronomic practices known that enable the production of the crop on a commercial basis? Does suitable processing technology for the crop exist? are techniques for handling the final products from the crop known? Are the various technologies compatible within the emerging system?

In addition to the question of knowledge of physical possibilities, there is also the question whether the function can be performed even if the knowledge exists. This is analogous to the "development" aspects of "R & D". In many cases, the function is physically possible because it is similar to and can be borrowed from a comparable one for an existing crop system. But where borrowing is not possible, R & D efforts are needed to determine how the function can be performed. Often technology can be adapted with varying degrees of inefficiency to demonstrate the potential of the new crop system and define the nature and scope of further research and development.

But just because the function is physically possible does not mean it will be performed. There must be incentives to do so. In the private sector there must be profit rewards to make the risks worth undertaking. In the public sector there must be public service awards to both motivate those undertaking the functions and justify the continuation of appropriations to do so. Sometimes the public incentive may be a reduction of public payments for surplus production of traditional crops.

Regardless, each and every function must be economically feasible in the sense of responding to incentives. Especially with new ventures such as those dealing with new crop systems, the potential rewards must be appreciable relative to the inherent investment risks.

The question of institutional permissibility is not as obvious as those of physical possibilities and economic feasibilities. Several examples may help illustrate this concept that has both sociological and legal implications. Some farmers may be reluctant to grow grain amaranth because it is related to and looks like "pigweed". Early efforts to convince existing U.S. pulp and paper mills to try kenaf ran into subtle resistance from pulp masters who were not interested in being the first in the industry to pulp weeds instead of wood.

Then, as an example of legal constraints, there is a need to obtain an EPA clearance in order for a pesticide to be legally used on a new crop. For example, even though kenaf may have promising potential as a forage fiber for ruminants as shown by the research being conducted by ARS in El Reno, OK, clearance from the various agencies to add kenaf to the label of common cotton herbicides will be delayed if kenaf is to be introduced into the food chain. Therefore, all work in this area are being done with the assurance that kenaf will not be used for either food or feed. Those clearances will come later.

Suffice it to say, even if the functions in the PMC system are physically possible and economically feasible, they may not be performed if they are not institutionally permissible. This institutional issue is generally overlooked in many developmental efforts spearheaded by engineers and economists. However, the high risks presented by the need to get approval from a host of agencies at the earliest stage creates the very real need for cooperation between private and public sector interests.

Regardless of where the constraints are in the system, a strategy (or series of coordinated strategies) is needed to overcome them in an efficient manner. Here, efficiency is defined in terms of both costs and time. Given the long lead times frequently required to overcome some new crop constraints such as seed increases, agrochemical clearances, etc., a time-phased "game plan" is vital and lends itself especially to a public - private sector partnership. The PMC matrix, therefore, represents the beginning point for strategy formulation activities designed to lead to the commercialization of a new crop system.

The PMC System Matrix

In most cases a new crop is not totally new. That is, it is not completely unknown. However, much of the information about the plant and its possible uses is fragmented and scattered around the world's research community. Such information is often not readily available to a single group of decision makers. As a consequence, the PMC System Matrix is a useful conceptual tool for compiling data about constraints, whether physical, economic, or institutional in nature.

For example, there may be data or experts or both available in a given part of the country who are aware of this agroclimatic conditions under which a given plant type will perform well. On the other hand, in a completely unrelated discipline, organization, and/or location, there may exist expertise that can identify the types of equipment required to harvest such a crop. Further, in the

marketing subsystem, there may be similar individuals, unknown to those mentioned above, who are aware of the types of processing technologies required by the new crop system, including those which may make byproducts possible. Finally, in still another location, there may well be expertise as to how best to penetrate a given market with the intermediate or final products.

The PMC System Matrix can assist in identifying where these constraints exist as well as organizing and disseminating information regarding possible actions to redirect and better integrate system components by potential participants. The PMC methodology that was developed in a 1981 study funded by the National Science Foundation incorporated the Delphi technique, viz., a survey procedure with feedback to respondents, to identify where the knowledge gaps are and the most logical means by which they can be remedied (5). This methodology can be used to explore new uses for existing crops or evaluate proposed uses of biotechnology and other new technologies. One "side" result of the information gathering and sharing process is the development of interest groups that gradually take on the challenge of putting the new crop system together, as has happened with kenaf.

Having identified the constraints to the establishment of a new crop system, be they physical, economic, or institutional, a new crop establishment strategy can be formulated, monitored, and adjusted. That is to say, it is possible to identify specific activities that have to be performed in a given sequence in order to efficiently establish a system for the new crop. Given the long lead times required to deal with individual constraints, the careful orchestrating of the process is essential for efficiency. Even with the best of efforts, given the uncertainties involved, a substantial amount of flexible pragmatism will be required. However, the process should not be totally uncoordinated as now appears often to be the rule.

Frequently, the remedies to the lack of coordination are an inappropriate institutional response and may be worse than the original problem, e.g., substantial funds and manpower can be directed to a centralized, heavily managed information collection organization or association of public researchers that becomes over time yet another permanent part of a growing bureaucracy. Rather, the example of kenaf that follows is testimony to the great American tradition of staying "lean and mean", maximizing results from minimal, carefully managed resources. Developing as well as implementing strategy is a creative process. Institutional flexibility is a critical factor not generally considered to be an attribute of most public institutions or programs.

An Action Model: The Kenaf PMC Story

Kenaf, an annual hibiscus fiber crop, is relatively new to the United States, but has been grown primarily in Asia and Africa for centuries. Much of the following has been covered in greater detail elsewhere (6). This discussion reviews the crop's status before being evaluated using the PMC System Matrix, presents the strategy formulated, and examines the results.

Kenaf's Historical Perspective

Kenaf, as a cordage crop in Asia and Africa, had received relatively little attention from plant scientists other than an occasional botanist up to the initial stages of World War II. Then this "backyard" fiber crop of indigenous farmers began receiving serious attention from western

agriculturalists. The reason: the supply of jute fiber from Asia was in danger of being denied America by the growing Japanese presence in the region. The United States had become dependent on imported cordage fibers, especially after shutting down domestic hemp production.

Those events brought kenaf to the Americas where it was grown experimentally in Florida and the lower Rio Grande Valley of Texas during the early 1940s. After the war, traditional jute suppliers re-entered the international market. The kenaf work in Florida proved to be too labor intensive to compete with imported fibers. Therefore, the kenaf program shifted to Cuba in the 1950s in search of lower labor costs. With the change in governments in Cuba, the kenaf cordage work moved on to Central America where small bag making operations based on kenaf still exist.

Without going into extensive detail, the kenaf cordage program benefited from a multi-disciplinary research focus by the USDA's Agricultural Research Service and other agencies as well as selected land grant universities. Important crop improvement objectives of plant uniformity, disease resistance, etc. were achieved by the kenaf researchers and incorporated in new varieties such as the Cuban, Everglades, and Guatemalan lines. This work succeeded in "domesticating" the crop for U.S. farmers. Unfortunately, the inadequacy of harvesting and processing technologies coupled with high labor costs did not permit entry of U.S. kenaf fiber into the cordage markets.

About the same time that the U.S. role in developing kenaf as a cordage fiber crop was winding down, another USDA effort initiated a search for an annual crop source of fiber for the nation's pulp and paper industry. This "new fiber" search considered some 435 plant species and concluded in the mid 1960s that kenaf was the best candidate. Further work was conducted in the lab and in the field to establish kenaf's potential as a pulp fiber. The public efforts were terminated in the mid 1970s as other national priorities took precedent.

The statement, "time is of the essence", is prominent on most legal documents. Timing is also crucial to the development of a new crop system. During the 1960s when kenaf was being considered as an alternative fiber for pulp and paper manufacturers, wood supplies were relatively inexpensive and seemingly abundant. When approached by USDA to consider kenaf, most companies gave only polite attention. Those that did look at kenaf were concerned about harvesting and storing an annual crop source of fiber. The technology gaps appeared serious and led to the proverbial stand-off between agricultural interests not willing to invest in testing equipment systems without a commitment from industry and industry not interested in making a commitment for a fiber whose supply was not necessarily dependable or economic.

Ironically, some of the events that led to USDA ending its fiber crop work to study renewable energy crop possibilities, also had a role in the escalation of newsprint prices from $176 per metric tonne in 1970 to $500 in 1980. U.S. newspaper publishers became concerned in the late 1970s that having 60 percent of their newsprint requirements dependent upon imports was too risky and they began to look for alternatives.

Publishers were aware of the USDA efforts with kenaf that had resulted in a small press run with the Peoria Journal Star, and the chairman of the American Newspaper Publishers Association (ANPA)'s Newsprint Committee, Mr. Donald Soldwedel of Yuma, Arizona, determined to build

on the USDA work. ANPA succeeded in enlisting the cooperation of the International Paper Sales Company and the late Walt Kammann of Yuma put in a kenaf crop in 1978 of about 40 acres. This represented the first concrete steps taken by the private sector that have progressively led to the current demonstration of kenaf's feasibility.

The adventure began. Eventually, kenaf was pulped at C-E Bauer's pilot plant in Springfield, Ohio and kenaf newsprint was made at International Paper's former newsprint mill in Pine Bluff, Arkansas in late 1979. The limited amount of newsprint was printed on by six newspapers.

A second run of kenaf newsprint was made at International Paper's mill in Mobile, Alabama in 1981 with eight publishers participating. Meanwhile, I initiated work on a systems approach to new crop introduction at the University of Missouri supported by a grant from the National Science Foundation in late 1979. Lastly, a seemingly unrelated event took place in northeastern Thailand as the world's first kenaf kraft pulp mill initiated operations in 1981, based in large part on technologies developed by USDA.

Evaluation of Kenaf's PMC System

A review of the literature which was complimented with interviews of the variety of individuals who had been involved with some aspect of the recent kenaf work. As such contacts took place with experts in the agricultural, industrial, and publishing sectors, the author noted that most of the individuals operated with limited to no information as to what was going on elsewhere in the emerging kenaf system. That is, a plant breeder was generally poorly informed as to processing work being undertaken on kenaf. The system of refereed journal articles moves at too slow a pace and only to somewhat restricted audiences in order to adequately and effectively disseminate information to crop system participants.

The PMC system research itself served to address some of the communication needs of the emerging kenaf system. However, it still amazes and saddens me that far too many researchers in both ARS and the various universities seem to prefer to operate with their blinders on and relate little if at all with private industry. This may be attributed to a desire to avoid real world criticism and accountability. Obviously, such attitudes contribute directly to the inefficiencies described earlier.

In addition to the need to circulate information throughout the system, the evaluation soon highlighted the following deficiencies:

- inadequate kenaf seed supply to meet potential needs of kenaf farmers ?
- limited crop experience on farmers' fields...data based on small experimental plot work, while encouraging, are not enough to give the rest of the system confidence that farmers will be able to deliver large amounts of fiber in a dependable fashion

- nematode concern: most kenaf varieties are susceptible to attack from nematodes...this was initially seen by industry observers as a major constraint limiting kenaf's viability as a dependable fiber source

- need to engineer a complete harvesting, handling, storage, mill introduction system to assure an efficient and dependable supply of fiber to a mill on a daily basis

- natural indifference of most existing mills due in part to some of the above concerns and to the reluctance of a nearly oligopolistic industry to innovate when they can merely pass on higher costs in higher prices

- high financing requirements: a new, greenfield newsprint mill will cost approximately $350 million to design, equip, and construct with another $75 to $100 million if it needs its own power generation capability...this means that projected returns must compete with projects of similar risk, interest rates will have a direct impact on profitability, and the project is very sensitive to recent changes in the tax codes that affect capital formation

- a kenaf system champion -- even when everything appears to be in place, someone needs to take charge to fully form the system and bring it into being.

Kenaf System Strategy -- Formulation and Results

The activities being described were dynamic and fluid -- an action-oriented research and development effort. Therefore, specific strategies were defined, tested, and frequently abandoned; it was not always clear which happened first, the strategy or the event. In formulating crop system strategies, we reviewed the system using the matrix and, in consultation with kenaf experts, defined priorities.

For example, the need for a strong kenaf system champion quickly became a focal point requiring action in order for the system to form. Such a champion needed to be in the private, profit-oriented sector as public agencies and universities will soon run into conflicts of interest, institutional inabilities to move quickly with vital flexibility, and other, generally institutional, limitations. The latter should not be viewed as negative limitations on the public sector, but as rationale for designing their involvement to efficiently interact with private sector interests. Too often, public agencies are forced into leadership roles because private firms decline to assume the responsibility.

In addition, it was postulated that for an entity to become an effective system champion, they would need a system wide perspective. Kenaf International, a joint venture company formed by a leading Californian newspaper publisher, an international agricultural production and management company, and a research firm, came into being in late 1981 to meet the challenge of championing the kenaf system into existence.

Kenaf International immediately acted on its own to develop a kenaf seed supply and invested the necessary resources to remove this constraint over the next six years. Kenaf International's high risk investment in developing a kenaf seed supply has made it possible for major projects to be considered by the industry. An inadequate seed supply would increase the developmental time horizon beyond that considered practical by industry.

Kenaf International personnel participated in the preparation of a study report on the feasibility of a kenaf newsprint system in the United States for the ANPA and in the subsequent International Kenaf Conference sponsored by ANPA and held in San Francisco on April 29, 1982. These activities served to formally introduce the company and its purpose to potential system participants.

Again, considering the system constraints identified via the PMC System Matrix, the company began to address the needs to test kenaf thoroughly under farmers' field conditions, to better define the potential impact of nematodes on fiber production, and to initiate activities that would eventually result in the development of an efficient harvesting and handling system for kenaf.

Kenaf International also sought out a relationship with a major U.S. manufacturer in an attempt to overcome the perceived industry indifference cited above. Discussions at the highest levels came to naught when that manufacturer decided to withdraw from newsprint entirely and concentrate on other products.

The strategy shifted and called for developing kenaf projects overseas because institutional constraints seemed less restrictive than in the States. Funding assistance for feasibility studies and project development work was much easier to identify and obtain for international projects than for those with a domestic focus. The company with support from various international development agencies and other sources explored kenaf's potential in a variety of countries.

Ironically, while study funds were relatively available for third world countries like Belize and Pakistan, it soon became apparent that investors would be hard to find and financing would be difficult if not impossible. As a partial compromise, Kenaf International began exploring the possibility of locating a small newsprint mill in Puerto Rico.

After nearly a year of study, the high cost of power and bureaucratic frustrations made the company's officials receptive to an invitation to discuss kenaf's potential for U.S. farmers with the Deputy Secretary of Agriculture in mid 1985. These discussions were followed by a quick succession of meetings that included Kenaf International and USDA personnel visiting various industry representatives. During this same time period, Kenaf International was challenged by its contract seed producer, Rio Farms, Inc. of Monte Alto, TX to seriously consider the lower Rio Grande Valley as a potential site for a kenaf newsprint project.

An initial study of the Valley and the project's potential economic feasibility was positive. Kenaf International decided to redirect its, efforts to focus on developing a project in the United States, specifically South Texas.

In early 1986, Kenaf International and USDA signed a Cooperative Agreement to jointly pursue a series of steps expected to lead to the commercialization of kenaf as a new crop for U.S. farmers, a new source of fiber for U.S. pulp and paper manufacturers, and a new domestic source of newsprint for U.S. newspaper publishers. The USDA assisted Kenaf International in forming a system-wide Kenaf Task Force to attack the remaining technical problems and test the system from field to pressroom.

The Agreement has proven to be a successful way to bring together private and public resources (technical and financial) to expedite the system development process. It is amendable and lends itself well to the need for flexibility when moving through the uncharted territory of a new technology. For example, the original intent of the agreement was to pursue the development of kenaf as a new fiber source for existing mill. After a series of visits, both USDA and Kenaf International became convinced that the system needed to be tested before any existing manufacturer would be interested enough to contract with farmers.

Kenaf International and USDA were then joined by Combustion Engineering's Sprout-Bauer Division, the only remaining U.S. maker of pulping refiners, and CIP, Inc. (now Canadian Pacific Forest Products Limited), the world's second largest manufacturer of newsprint. The Beloit Corporation, the U.S. manufacturer of paper machines, also participated by making available its testing facility. Several other companies have also been involved in various aspects of the effort. The strategy implication here was that equipment suppliers were natural allies of farmers, publishers, and USDA in that they saw the possibility.of future sales through their cooperation in testing phase.

Kenaf fiber was grown by three Texas farmers and Rio Farms during the 1986 crop season. Harvesting the kenaf was a large scale trial and error process in which a series of equipment combinations were tried and generally found lacking...a learning experience. Kenaf was harvested, and the task force was able to postulate a harvest-handling system that should meet its requirements. The material was sent to Sprout-Bauer's pilot pulp facility in Springfield, Ohio, pulped, and sent to Beloit's pilot machine facility in Rockton, Illinois. In January 1987, kenaf newsprint was made, and it compared well with newsprint from southern pine and northern spruce under the same conditions.

Based on those most promising results, Kenaf International and its associates agreed to jointly pursue the development of the world's first newsprint mill to be based on kenaf. This included completing the system tests by pulping approximately 60 tons of kenaf and making enough newsprint on one of CIP's commercial machines in Quebec to run in selected pressrooms in Texas, California, and Florida. This commercial-scale demonstration completed the trial stage of the project development phase and is leading to the establishment of a kenaf newsprint project in the lower Rio Grande Valley of South Texas. Land has been acquired and Kenaf International is engaged in negotiations expected to lead to project implementation.

With the successful pressroom trials confirming that quality newsprint could be made from kenaf, the kenaf system development efforts continued on two related but separate tracks. The Kenaf Newsprint efforts are proceeding as a private sector project pursuing financing and customers. Kenaf International has been joined by the Bechtel Group and Sequa Capital to accomplish this

objective (a recent press release by Kenaf International regarding the formation of the Kenaf Paper Company of Texas has been attached). The USDA-land grant system will be called on to provide its traditional research and extension support to local kenaf farmers as the commercial interests become established.

The Kenaf Task Force has turned its attention toward completing the design and testing of the harvest-handling system, more growing trials at various sites, presentations to existing mills of trial results, and the development of other products from kenaf. The latter efforts have proven quite encouraging and it is highly likely that new uses for separated kenaf fibers could parallel the fiber's introduction as a new fiber source for the pulp and paper industry. Stay tuned for further announcements.

Conclusions and Implications

The expected capital investment of the first phase of the Kenaf Paper Company's newsprint project is estimated at $35 million. It will generate about 160 direct jobs and about $1.4 million in annual payments to local farmers. USDA's investment to date has been about $1.8 million, which has been matched nearly 4:1 by the other members of the task force. No elaborate computations are necessary. It looks like an excellent return on investment for both the private sector and the U.S. taxpayer. In addition to the above, Kenaf International is close to a decision point on another approximately $3 million investment that will open up several new industrial uses for kenaf fiber. Assuming that about two-thirds of the public funds spent on kenaf since 1986 actually escaped the ARS porkbarrel, the return in private investment to public expenditures exceeds 3,500%.

What does all of this mean as far as other efforts to meet the needs of the nation's farmers without bankrupting the treasury, sparking commodity trade wars, or reverting to further social experimentation with production controls. As Senator Harkin so aptly put it: "Too often, we only have half of the R&D equation -- we have research without the development." (7) The system approach described above is an example of focusing on developing and commercializing technology.

USDA has estimated that its previous research efforts on kenaf had cost approximately $10 million up through the 1970s. This research investment was largely consigned to the files until department personnel, encouraged by the Chairman of the House Agriculture Committee, utilized the provisions of the 1985 Farm Act to cautiously attempt to complete the loop by working in partnership with private companies.

Neither U.S. agriculture or industry is well served in the long run by government subsidies or other interventions in the market place. The public role that seems more appropriate is one in which the government works as a partner to help cover the inherent risks involved in the introduction of a new technology ... diminishing its role as the project develops enough to attract conventional financing.

The Cooperative Agreement approach used by USDA in the kenaf project is one model that could be successfully adapted to other system development efforts. Another model which might be

borrowed from the State Department's Trade and Development Program is a reimbursable grant program that shares some of the development costs of putting together a project based on new technology.

The point to be made here is that merely pouring more money into research programs and the political game of creating more "institutes" named for members of congressional appropriation committees could be an unwise investment if no provision is made for the commercial development of the technologies to be generated. Understand that Kenaf International's approach to kenaf's development has been light on both overhead and bricks and mortar. Those come after a system has been developed, not before. Without incorporating a systems concept in the decision-evaluation process, society will continue to run the risks of investing in research without necessarily reaping the results.

Finally, a plea is made that a greater effort be made by all concerned with the proper establishment of new crops to clean up your act. Kenaf International has purposefully chosen not to participate in most promotional associations due to the type of forum provided. We have observed that the net result of such groups is a deserved perception that many researchers "working" on new crops are either incompetent or corrupt or both. History is quite clear that there are no short cuts with the introduction of new crop systems...they can take years of effort, million of dollars, and great tolerance of frustration. They will not happen without the long-term commitment of people throughout the emerging system who share a vision that they pursue with open integrity.

NOTES

(1) *Blase, Melvin G.* 1985. Testimony presented to the Joint Economic Committee of the U. S. Congress. Much of the current paper is adapted from this and other presentations by *Dr. Blase* and the author, either individually or jointly.

(2) Center for National Food and Agricultural Policy. 1984. Ten Year Forecast for U.S. Agricultural Sector

(3) *Schumpeter, Joseph A.* 1934. The Theory of Economic Development.

(4) *Taylor, Charles S.* 1984. A Systems approach to the Commercialization of Kenaf. Ph.D. Dissertation, University of Missouri-Columbia (Department of Agricultural Economics).

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(6) *Kugler, Daniel E.* 1988. Kenaf Demonstration Project. USDA.
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1988 Oklahoma Kenaf Research

By

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Kenaf research and demonstration studies were established at six separate locations in the state of Oklahoma during the 1988 growing season.

Three of the six locations were established in cooperation with Kenaf International. These studies involve 5 acre blocks located at Merritt, Elk City, and Yuba, Oklahoma. Kenaf cultivar Everglades 41 was planted at each location and with the addition of Everglades 71 at Yuba. The Merritt and Elk City field trials were planted on June 3, 1988 in 16 in. rows with final plant populations of 138,000 and 205,000 plants/a. Poor soil moisture, low rainfall, and delayed planting produced yields of 4.8 and 3.7 tons/a at the Merritt and Elk City locations respectively (all yields discussed are oven dried stalk weights at 0 % moisture). The kenaf at Yuba was planted in 36 inch rows on May 14, 1988. Final plant populations average 75,000 plants/a. Everglades 41 averaged 6.7 tons/a compared to 5.2 tons/a for Everglades 71.

Two demonstration blocks were planted in cooperation with Kenaf of North America and Oklahoma State Extension Service. These plantings were one acre blocks of Everglades 41 planted at Fort Gibson (May 19, 1988) and Haskell (May 10, 1988), Oklahoma. The kenaf was planted in 30 inch rows with final plant populations of 28,000 and 23,000 plants/a for Fort Gibson, and the Haskell locations respectively. Final dry weights for Fort Gibson and Haskell were 9.8 and 4.6 tons/a.

A kenaf irrigation study was planted on May 20, 1988 at Lane, Oklahoma. The kenaf cultivar Everglades 41 was planted in a split block design with main plots being irrigation treatments, and row widths as subplots. Irrigation treatments involved irrigating one main plot when soil tensiometers read 25cb and the other at 65cb. The differential irrigation treatments were applied from July 14, to August 12, 1988. When the stress treatment was initiated on July 14, rainfall for the Lane research station was 10.8 inches below the yearly average. During the stress period, when only 0.82 in. of rain was received, the 25cb treatment received 8.5 inches of irrigation water compared to 3.00 in. of water for the 65 cb treatment. Plants in the 65cb treatment exhibited a great deal of wilting between irrigations. The 65cb stressed plants resumed growing once regular irrigations were continued on August 16, 1988. Each main plot had row widths of 14 and 36 inches. Final plant populations for the 14 and 36 in. row widths averaged 222,000 and 74,000 plants/a respectively. The average dry matter yields for the 25cb irrigation treatment were 6.2, and 6.7 tons/a for the 14 and 36 in. row widths, while the 65cb irrigation treatment had yields of 6.4 and 5.4 tons/a for the 14 and 36 in. row widths.

The six kenaf locations in 1988 with the various plant populations and water availability produced a wide range of final dry matter yields. The research demonstrated a good potential for kenaf production in Oklahoma, but it also identified the need for more detail studies on the relationship of plant populations, varieties and water use for selected locations in Oklahoma.

1989 Oklahoma Kenaf Research

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As a result of six kenaf research and demonstration locations in 1988 a series of kenaf research studies were started in 1989 at a wide range of locations in Oklahoma and northern Texas. The research studies in 1989 involve row spacing, plant population, fertility, variety, and herbicide studies with kenaf.

Four locations had a row spacing by variety study. The three row spacings were 10, 20, and 30 inch spacings. Each row spacing treatment was also planted in two varieties, Everglades 41 and Tainung #1. The row spacing study was planted at Ladonia, and Lubbock, Texas and at Merritt and Lane, Oklahoma. Three locations in Oklahoma had a plant population by variety study. The plant population treatments were 75,000, 150,000, and 225,000 plants/a with each of the two varieties of kenaf cultivars Everglades 41, and Tainung #1. The plant population studies were planted in 20 inch rows and located at Keota, Walters, and Lane, Oklahoma. Each of these studies provided additional information about cultural aspects of kenaf production in Oklahoma and Texas.

Two studies in 1989 were initiated to investigate the possibility of using kenaf as a forage crop with the option of letting the crop continue to grow and produce a fiber crop. The research locations for the forage studies were Ladonia, Texas and the Oklahoma State University's Eastern Research Station, Haskell, Oklahoma. The forage crop studies involved at least four kenaf varieties and three harvest dates.

Research studies investigating the fertility requirements of kenaf were located at Lane and Moore, Oklahoma. The Lane research study had five nitrogen rates (0, 50, 100, 150 and 200 lb/a). The fertility research at Moore, Oklahoma was in cooperation with Farm Soil Conditioner Inc., Cow Creek Wastewater Pollution Control Facility. The Moore, Oklahoma research study had four rates of sewage sludge application (0, 4, 8, and 12 tons/a), irrigated and non-irrigated treatments, and four rates of commercial fertilizer.

ditional kenaf research initiated during the 1989 growing season involved kenaf variety trials, and kenaf herbicide studies. Many of the research studies conducted during 1989 will be repeated during the 1990 growing season. In contrast to the low rainfall levels of the 1988 season, rainfall in 1989 was above normal during May, June and July at most research locations.

Kenaf In Australia: A Progress Report On Research And Development

By

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Abstract

The first detailed studies undertaken in Australia on kenaf were conducted by CSIRO between 1972 and 1981. A field program covering agronomy and genotype evaluation was conducted in the Ord Irrigation Area (OIA) in northern Western Australia and harvesting studies were conducted in Queensland using sugar cane and forage harvesters. Research on the pulping and papermaking properties of kenaf was conducted by the then CSIRO Division of Chemical Technology to complement the agronomic research. In contrast to the US studies, the emphasis was on the separate pulping of the bark and core fractions and on the use of freshly harvested material. The studies covered chemical and semi chemical pulping and the mechanical processes of TMP and CTMP. In 1981 in the absence of commercial interest the kenaf research program was discontinued. However, some agronomic and pulping studies on Sesbania, another potential pulp crop were continued up to 1984.

In 1983 Ankal Pty Ltd, began a commercial assessment of establishing a pulp and paper industry based on kenaf in northern Australia. In 1984 following detailed market and economic surveys the company arranged for trial sowings in the Burdekin River Irrigation Area (BRIA) in northern Queensland. Between1984 and 1987 a number of farm sowings were made to obtain yield data and information on difficulties associated with growing kenaf in the BRIA. Mechanised harvesting trials using sugar cane and forage harvesters were also conducted and some 400 t of stem material was harvested for trial pulping. Ankal Pty Ltd is presently undertaking trial sowings in the Murrumbidgee Irrigation Area in NSW.

The Queensland Department of Primary Industries began research on kenaf in the BRIA in 1984 and have examined crop responses to water and fertilizer. A 3-year program funded by the Federal and State Governments is due to terminate in June 1989. This program is examining the incidence of disease and evaluating a range of genotypes. The latter studies are aimed at determining the effects of photoperiod and temperature on flowering.

In 1988 the Northern Territory Government began studies to assess the potential for a kenaf-based pulp and paper industry in the Northern Territory. These have included market appraisals, mill site studies, economic analyses and agronomic studies. The CSIRO was contracted to develop a kenaf growth model and this should be completed by December 1989. The NT Government is currently seeking private investment in a commercial joint venture operation.

Introduction

In the period 1972 to 1981 an intensive research program was undertaken by CSIRO in northern Australia to assess the possibilities of developing a kenaf based pulp and paper industry. Athough the results indicated reasonable commercial prospects there was little commercial interest and the decision was made to terminate the program.

During the past 7 years there has been an increasing commercial and public interest in the use of kenaf as a feedstock for the pulp and paper industry. This interest has been partly prompted by public opposition to the cutting of native forests for local production of pulp and paper and for the production of woodchips for export. Other factors have been the growing awareness of the extent of the decline in the native forest resources during the past few decades and of the current high level of imports of pulp, paper and board into Australia. The excess of the cost of imports over exports amounted to Aust $1.36 billion during 1987-88, a significant cost at a time when Australia is experiencing a serious balance of payments problem.

This paper briefly outlines the research undertaken in Australia on the utilization of kenaf for pulp and paper production and the progress made towards development of a commercial industry.

Field Studies With Kenaf In Australia

Some of the earliest recorded trial sowings of kenaf and other fibre crops in Australia were made in Darwin in the Northern Territory (NT) in the 1880s (Wood and Hearn 1985). In the early 1950s further trials were conducted at Katherine, NT following difficulties in securing adequate supplies of sacking fibre during the India -Pakistan conflict of 1949. Although the trials proved successful the work was discontinued when fibre supplies again became available from India and Pakistan.

In the late 1960s and early 1970s a number of exploratory trials were sown in NSW and Queensland as a result of publicity on the US studies. These trials aroused considerable local interest but no sustained commercial interest.

In 1972 a review was undertaken of the prospects of growing fibre crops in the Ord Irrigation Area (OIA) in northern Western Australia (Wood and Angus 1973). This review indicated that, with irrigation, kenaf could probably be grown year-round and that there were reasonable prospects that it could be used to produce paper pulp at a cost competitive with wood pulp. Subsequently an agronomic and varietal improvement program was conducted at Kimberley Research station in the OIA from 1972 to 1980. Complementary harvesting studies were conducted in Queensland using sugar cane and forage harvesters.

By 1981 it was considered that the basic information necessary to establish a commercial industry had been obtained and in the absence of local commercial interest it was decided to terminate the program. The results of the agricultural and industrial research conducted between 1972 and 1981 were presented at a national conference held in Brisbane in May 1981 (Wood and Stewart 1981). Research completed since the Conference has been reported in papers by Muchow and Wood (1983), Wood et al. (1983), Charles-Edwards et al. (1983) and Wood and Done (1983).

Since 1984 the Queensland Department of Primary Industries (QDPI) has conducted a kenaf research program in the Burdekin River Irrigation Area, partly in support of the demonstration sowings made by Ankal Pty Ltd. This program examined the water and fertilizer requirements of kenaf and the incidence of disease. Studies were also conducted on a range of genotypes ranging from early to late maturity grown at regular intervals throughout the year. This work has had the aim of developing a procedure for predicting flowering date, one of the most important determinants of stem yield. During 1988-89 the phenology study was extended with a series of sowings made at 6 widely separated sites. These ranged from the Murrumbidgee Irrigation Area (MIA) in southern NSW (lat.34°S) to the 'Top End' of the NT (lat.13°S).

Commencing in 1986-87 the NT Government has undertaken field trials in the higher rainfall 'Top End' of the Territory. These have concentrated on kenaf but have also examined roselle *(Hibiscus sabdariffa)*, Sunn hemp *(Crotalaria juncea)*, Congo jute *(Urena lobata)* and *Sesbania* spp. A feature of the field studies has been that they have concentrated on rain-grown production on loamy (Tippera, Tindal) and sandy (Blain, Venn and Oolloo) soils in areas having seasonal rainfalls of 950-1150 mm. This contrasts with other Australian studies which have tended to concentrate on irrigation cropping on heavier clay soils.

In 1988 the NT Government contracted with the CSIRO Division of Tropical Crops and Pastures to develop a kenaf growth model. Good progress has been made, with all the field work and much of the programming completed (Muchow and Carbery, personal communication). The model is process based and takes into account crop response to temperature, soil water potential and radiation. It incorporates a sub-model that permits prediction of time to flowering for any combination of sowing date and latitude. It is planned to use this model in conjunction with historical rainfall data to predict the likely variation in seasonal yields and to assess the likely difficulties in achieving early sowing and good establishment in this semi-arid tropical area.

Pulping Research In Australia

Research on pulping and papermaking properties of kenaf was conducted by the then CSIRO Division of Chemical Technology (now Division of Forestry and Forest Products) between 1973 and 1980 to complement the agronomic research being conducted in the OIA by the Division of Tropical Crops and Pastures. In contrast to the US studies, the emphasis was on the separate pulping of the bark and core fractions and on the use of freshly harvested material.

The studies covered chemical and semi-chemical pulping and the mechanical processes of TMP and CTMP, and have provided the basic technology necessary to pulp the two fractions (Watson et al.1976, and papers in Wood and Stewart 1981). There was a clear conclusion that kenaf is technically satisfactory for a range of pulping processes and paper products. In mechanical pulping studies the bark fraction gave very high strength pulps and the whole stem gave CTMP pulps with a satisfactory balance of properties. A feature of the production of mechanical pulp from kenaf was the reduction of about 30% in the energy requirement compared with wood. The core fraction gave pulps with acceptable bonding properties and excellent surface characteristics, but low tearing strength.

Commercial Developments

In Queensland: In 1983 a Sydney company, Ankal Pty Ltd, began a commercial assessment of the possibility of establishing a pulping industry based on kenaf in northern Australia. In 1984 following detailed market and economic surveys the company arranged for a number of farm sowings in the Burdekin Irrigation Area (BRIA). These sowings were used as demonstration areas and to provide yield data and information on difficulties associated with growing kenaf in the BRIA. Some difficulties were experienced due to the unfamiliarity of the farmers with the crop but generally the results were promising. During the 1986-87 wet season 20 ha were sown in the BRIA and 3 ha in the Mackay district.

In 1987-88 Ankal Pty Ltd transferred its operations from the Burdekin to the Murrumbidgee Irrigation Area (MIA) in southern NewSouth Wales. Ankal Pty Ltd have tested various methods of harvesting and have undertaken pulping studies of the harvested material. The company has adopted the approach originally developed by the CSIRO Division of Chemical Technology of separately pulping the bark and core fractions. However, instead of harvesting fresh material they have adopted the practice of allowing the crop to dry down in the field and then harvesting the dry standing material with a combined forage harvester/baler which produces 500kg bales. These bales are subsequently fed through a patented separation unit which separates the bark and core. The unit is reported to be capable of a continuous throughput of 20 AD tonnes of stem material per hour and to give bast fibre of 94-99% purity. The company has undertaken mill design and environmental studies for a 50 000 tpy bleached chemical pulp mill in the Murrumbidgee Irrigation Area in southern NSW. In New South Wales In 1988 Ankal Pty Ltd began kenaf trials in conjunction with the NSW Department of Agriculture in the Murrumbidgee Irrigation Area of southern NSW.

In the Northern Territory In 1986 the Northern Territory Government and News Ltd jointly commissioned a preliminary feasibility study to assess the potential for a kenaf-based pulp and paper industry in the Northern Territory. The study was undertaken in February 1987 and specifically examined the possibilities for producing magazine stock of the quality being imported into Australia by News Ltd. The possibilities of production for both domestic and export production were examined. The economic analyses proved sufficiently promising to warrant a more detailed examination of some key cost components and some aspects of marketing and industrial processing. An important factor was the availability of natural gas from a recently completed pipeline between the D Basin, west of Alice Springs and Darwin.

The NT Government subsequently began a comprehensive program which examined all aspects relevant to setting up and operating commercial industry. The program included market analyses, pulping and papermaking tests on kenaf, assessment of potential mill sites, estimation of potential growing areas, field studies, development of a simulation growth model for kenaf, preliminary analyses of farm and mill economics and a review of environmental impact.

The Northern Territory Government recently engaged consultants to prepare a commercial investment proposal which incorporates all the technical, economic and marketing information obtained to date. This was done with the objective of attracting private investment into a joint venture operation with the NT Government. Negotiations with potential investors are currently taking place.

Conclusion

Field trials have now been conducted in the four northern Australian States of NSW, Queensland, Northern Territory and Western Australia. As described above commercial proposals have reached an advanced stage in NSW and the NT.

In 1988 the Western Australian Government investigated the potential for a kenaf pulp industry in the Ord River Irrigation Area and in a document outlining their findings invited potential developers to participate in developing a kenaf industry,

The Queensland Department of Primary Industries has recently published a report entitled 'Kenaf in the Burdekin River Irrigation Area' which reviews the results of the kenaf sowings during the past 4 years and details the perceived constraints to production (Hazard et al. 1989). The report also examines in detail the economics of kenaf production in the BRIA and indicates the yield/price combinations necessary for kenaf to competitive with alternative crops grown in the region.

The current opposition to the cutting of native eucalypt forests for pulp and paper production and the current balance of payments problems in Australia may well prove to be the catalyst necessary to get a commercial kenaf-based pulp industry established in Australia.

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Kenaf Panel Discussion

Daniel E. Kugler, Chairman, USDA-CSRS-SPPS, Washington, D.C.
Marvin O. Bagby, USDA-ARS-NRRC, Peoria, Illinois
Andrew W. Scott, Rio Farms Inc., Monte Alto, Texas
Charles S. Taylor, Kenaf International, McAllen, Texas
Ian M. Wood, CSIRO, Brisbane, Australia

The panel was asked to give a 5 minute response to the question "What is needed to advance the research and development of kenaf...for agriculture and for industry?" The panel then participated in an open question and answer session with the 35 people attending.

Panel Responses

Kugler. In a very broad sense, those involved with research and development for kenaf need to (1) understand the role they must play in education and (2) overcome fears or inhibitions to work in many disciplines.

Education. Although research has been conducted in the U.S. for more than 40 years, it is still a new crop, a new agricultural raw material entering into manufacturing. Most people, people from all walks of life, know very little. Any research or development activity you engage in or prepare will undoubtedly require educating your associates. It is likely that you will be asked questions about every aspect of the vertical chain that includes kenaf, i.e. from seed and fiber production in the farming community to final manufactured product and product marketing. Note also that you must be well prepared if you expect to have fair and comprehensive exchange with your associates.

Fear/Inhibition. Commercialization of kenaf is still a process, not a result. In attempting to establish a kenaf related business, you will face the problem of having to work in many areas which you may have no previous experience. Any fear or inhibition you may have, to working in many often new disciplines will prove to be at your disadvantage. For those in agriculture, you must be ready to work directly with engineers, scientists, planners and managers in pulping, papermaking, and product marketing. Likewise the industry users of kenaf as a raw material need to be ready to work with the farm sector.

Paper industry relationship with forestry will need to be nurtured with farming. In the meantime, you need to become educated, to educate, and be prepared to deal with every aspect of a vertically integrated business which uses kenaf fibers.

Scott. Kenaf is still in need of private champions willing to understand and take the risks associated with credible agricultural development. The odds against coming up with a species which might be as successful as cotton are overwhelming. Kenaf may defy those odds.

On the agricultural side there are several needs. First, a variety of improvements are needed and the new breeding/genetics program at the ARS-Weslaco, Texas field station help us get started. We also need standardized methods and procedures for things such as yield determination, so that data is uniformly comparable. An urgent, short-term need is labeling of chemicals (herbicides, pesticides, seed treatments, etc.) for use on kenaf. Although state and federal programs can help, a national policy for new crops on the brink of commercial production may be needed to give agriculture a grace period or some other mechanism for legally using agricultural chemicals in the first few years of production for non-research purposes.

Wood. A systems approach to development of kenaf is what is needed and was very well covered in the presentation by Dr. Taylor this afternoon. Our program for kenaf development in Australia was terminated in the early 1980s because of lack of commercial interest. CSIRO's role, among other things, was pro-active and directed to determine why there wasn't industry interest. In that capacity, CSIRO learned that technologies for farming (farm scale) and for pulping/papermaking (mill-scale) needed to be proven before industry would consider kenaf for commercial businesses. Basically industry is content to sit on the sidelines and watch if someone funds and implements projects to prove agricultural and pulp/paper technologies at commercial scales.

CSIRO is planning to assemble a team of 30-35 people from industry, research, finance, conservation groups, etc. to start a dialogue on how to get past this current impasse. This team would meet first in February/March 1990 to outline a strategy for putting together the "best bet" technologies for location specific and product specific component activities.

The development gap we see in agriculture are similar to those you have attacked here in the United States. At a farm-scale, we need to prove systems for harvest, transport and storage of kenaf. Much work in the use of agricultural chemicals is needed, particularly in desiccants and defoliants because of kenaf's apparent tolerance of water stress. We also need more information on the nutrient drain on soils, the uptake and return of nutrients to the soil.

Taylor. For kenaf development to continue or start and be successful, you must have a market. This market is not only for the kenaf fiber produced by farmers, but also, perhaps most importantly, for the products manufactured with bast and core fibers. You have to offer more than theory to industry if you expect to open a new market. For example, a small scale research project and/or thoughtful discussions are not adequate for answering industry's questions about fiber supply reliability for risk analyses.

Be prepared to constantly redo your systems economics as information and changes come forward for investment/business requirements. On the environmental front, strange as it may seem, be prepared to demonstrate that you're not guilty. You'll have to show conclusively that your agricultural operations and pulp/paper/fiber operations will fall within predetermined limits for air, land and water uses and discharges.

Our experience in kenaf development stands as an example of how new crops and products can be brought to the market. It takes dedication and investment of resources by a multidisciplinary task force though the whole vertical system, from seed production to final product marketing.

This team must include major commitments the private sector and cooperation and support from government agencies and universities.

Bagby. Development of kenaf, and any other new crop or material, must emphasize a need or customer for the raw material and its products. Market pull is essential to development. This was the focus of the USDA-ARS work in the 1970s with the American Newspaper Publishers Association as a customer in anticipation of kenaf newsprint manufacturing. Your market, that is, the specific product line you select for a target will in turn dictate criteria for farming, harvesting, handling, pulping and papermaking. Each product line will require changes in the systems you develop, some changes being small, others being rather dramatic and costly, such as product lines requiring theromechanical pulping versus those for chemical or kraft pulping.

Kenaf germplasm needs attention. The USDA collection is being inventoried and plans prepared for re-newed testing in cooperation with the breeding/genetics program at Weslaco, Texas. George White at Beltsville, Maryland and Gil Lovell at Experiment, Georgia are principals for the collection. In particular, some advances in developing more cold tolerant varieties are needed to extend the range of geographic adaptation for pulp and fiber product manufacturing. The breeding/genetics program must pay attention to the fiber users. Be sure the user industry is directly involved in determining desirable changes in the physical properties of the fibers.

I also encourage additional research and development for utilization of kenaf in various products. The recent meeting in Chicago is an excellent example of seeking input directly from industry on wet-paper products other than newsprint for initial research and development.

I have two other concerns which are very high in my professional conduct for all my research and development, including kenaf. First, and I cannot stress this enough, be forthright in your knowledge. Anytime you persist in conveying unproven, false, or exaggerated data or information to the agroindustrial community, you are damaging all credible work. New crop development is just that, development. As such, it takes time, energy and money to make the advances necessary to mature a crop and its products for business. Second, stop and resist any impulse you or your co-workers may have to associate kenaf (Hibiscus cannabinus L.) with hemp (Cannabis sativa), a strong fiber crop whose tips, leaves and flowers contain an illegal resinous narcotic alkaloid. This simply and unnecessarily fosters an image problem.

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